AN EMPIRICAL TEST OF THE RELATIONSHIP BETWEEN SUSTAINABILITY AND URBAN FORM BASED ON INDICATOR COMPARISONS USING SUSTAINLANE SUSTAINABLE CITY RANKINGS

A Thesis

by

BO AH KIM

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2009

Major Subject: Urban and Regional Planning

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Approved by:

Chair of Committee,	Michael Neuman
Committee Members,	Shannon Van Zandt
	Ulrike Gretzel
Head of Department,	Foster Ndubisi

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ABSTRACT

An Empirical Test of the Relationship between Sustainability and Urban Form Based on Indicator Comparisons Using SustainLane Sustainable City Rankings.

(December 2009)

Bo Ah Kim, B.E.; M.E., Chung-Ang University

Chair of Advisory Committee: Dr. Michael Neuman

Sustainable development is one of the greatest challenges to urban planning in the 21st century. Current patterns of urban development, called byspecially sprawl, and human activity have led to environmental degradation and created a serious threat to continued human existence and sustainability of life on earth. The United States, concerns over consequences of urban sprawl have led to increased advocacy for more compact and traditional urban development. The compact city is now widely accepted as the most effective solution to sustainable urban form.

The purpose of this study is to examine the relationship between sustainability and urban form. In order to achieve the aims of this study, 50 cities in the United States are analyzed and compared with the 2008 sustainable city rankings from the organization SustainLane, using four categories of urban form indicators: densities, mode of commute to work, mean travel time to work & traffic congestion cost, and planning & land use. This research is based on the hypothesis that a sustainable city has a compact city form. According to the SustainLane 2008 US sustainable city ranking,

high ranked cities were considered more sustainable cities and low ranked cities were regarded as less sustainable cities. Using SPSS's correlation analysis tool, I studied the relationship between overall city ranking and four categories of urban form the indicators. The overall finding of the analysis of the relationship between each indicator and urban form yields mixed results.

The result of this research found that that sustainable city and urban form has several correlations; densities, mode of commute to work, and planning and land use have a strong positive correlation with sustainable city; however, mean travel time to work and traffic congestion cost have a negative correlation with SustainLane's sustainable city ranking. These results mean that sustainable cities which were high ranked cities in the SustainLane 2008 US sustainable city ranking have a high density, sustainable mode of commute to work, and strong planning and land use. Particularly, when a mixed land use, centeredness, and street connectivity were combined, the planning and land use category of indicators shows stronger correlation with sustainability. According to this result, these findings suggest that when the planning and land use indicators are combined synergistically compact urban form can be an indicator of a more sustainable city.

DEDICATION

To my parents and little brother

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Last but not least, I would like to share my pleasure in completing this study with my parents who have loved and supported me in every way.

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1. INTRODUCTION

Sustainable development has been one of the greatest challenges to urban planning in the 21st century. With the projection by the United Nations that 69.6% of the world's population and 90% the United States population will live in urban areas by the year 2050 (United Nations, 2007), it is apparent that the immediate global future is one of urbanization. An often-cited definition of sustainable development, the '*ability to make development sustainable-to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*' is from the Brundtland Commission (UNWCED, 1987). Also, the 2002 World Summit on Sustainable Development marked a further expansion of this definition with the widely used three pillars of sustainable development: economic, social, and environmental (Kates, Parris, & Leiserowitz, 2005). While most agree about the need for sustainable development, operationalizing this consensus goal in urban planning is extremely difficult. Despite its vagueness and ambiguity, the World Commission on Environment and Development (UNWCED, 1987) definition of sustainable development has been highly instrumental in developing a 'global view' with respect to our planet's future (Mebratu, 1998). Over the past 20 years a number of books and articles have been critical of sustainable development. Even though there are many books and articles, researchers are still looking for ways to achieve a sustainable urban future.

Among the numerous research reports, articles, and books, it is now widely

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accepted that a relationship exists between the shape, size, and density of a city and its sustainability. The relative sustainability of high and low urban densities or of centralized and decentralized settlements is still disputed (Williams, Burton, & Jenks, 2000). Also, despite many great efforts through generations, the paradox between urban desirability and suburban livability has yet to be adequately resolved. Recent attempts to halt sprawl and improve urban livability have been made by new urbanism advocates of compact city, smart growth, and healthy communities (Neuman, 2005). That is, certain urban forms contribute more than others to sustainability. Undoubtedly, this concept has motivated and provoked scholars and practitioners in different disciplines to seek forms for human settlements that will meet the requirements of sustainability and enable built environments to function in a more constructive way than at present (Jabareen, 2006).

The purpose of this study is to figure out the relationship between sustainability and urban form. In order to achieve the aims of this study, I will first review previous studies of the sustainability, urban form, and the relationship between sustainability and urban form. Second, among previous studies, I will analyze the SustainLane 2008 US sustainable city rankings. Third, I will compare these cities by indicators which are related to sustainable urban form, then attempt to explain the relationship between urban form and sustainability. Based on the SustainLane 2008 US sustainable city ranking results, there are high ranking cities and low ranking cities which this study will investigate further by examining the high ranked cities and the low ranked cities' urban form. The comparisons will show how these indicators are related to sustainable urban form and also present correlations among the indicators.

2. LITERATURE REVIEW

It is predicted that over half the world's population will live in urban areas where most resources will be consumed and most pollution and waste will be produced. The United Nations projects that 69.6% of the world's population and 90% the United States population will live in urban area by the year 2050 (United Nations, 2007). Current patterns of urban development and human activity have led to environmental degradation and created a serious threat to continued human existence and sustainability of life on earth. It has been argued that there are strong links between urban form and sustainable development (Masnavi, 2000). This section figures out the relationship between sustainable development and urban form and then defines the characteristics of sustainable urban form and its indicators.

2.1 Definition of Sustainable Urban Form

Since the world's first cities arose between 4,500 and 3,500 B.C. in the valleys of the Tigris-Euphrates, the Nile and the Indus (Lynch, 1954), urban form has changed dramatically. Throughout these changes, mankind has had the capacity to produce far more information than anyone can absorb, to foster far greater interdependency than anyone can imagine, and to accelerate change far faster than anyone's ability to keep pace (Senge, 1990). Parallel to this unprecedented labyrinth of complexity, mankind has a myriad of systemic dysfunctions, each with its own ecological, economic, and social dimensions without simple cause or solution. This has led to the evolution of new concepts, including that of sustainable development as a basis for overcoming environmental challenges (Mebratu, 1998). Particularly during the late 1970s and early 1980s, a number of independent scientists, activists, and policymakers were working on responses to the linked problems concerning issues of environment and development. Finally, in 1987, the United Nations' World Commission on Environment and Development released its report Our Common Future, which brought the terms 'sustainability' and 'sustainable development' into widespread use. Our Common Future (or the Brundtland Report), defined sustainable development as 'development which meets the needs of the present without endangering the ability of future generations to meet their own needs'. (UNWCED, 1987). This definition contains the concept of inter-generational equity and social justice, as well as environmental awareness (Haughton & Hunter, 1994). It also implies that a global perspective is necessary and cross-boundary impacts should be considered. Numerous analysts and researchers have come close to setting such definitions by developing characterizations of 'sustainable cities' or 'sustainable urban development'. Such descriptions usually include principles that sustainable urban form should adhere to (Williams, Burtin & Jenks, 2000). Previous research has provided the key elements of urban form; densities, compactness, concentration, dispersal, mix of uses, and housing type, etc. These elements offer new evidence which sheds light on the aspects of urban sustainability or alternative views of what sustainable urban form might be.

2.2 Sustainable Urban Form: The Compact City

The United States, concerns over consequences of urban sprawl have led to increased advocacy for more compact and traditional urban development. Compared to sprawl, compact and traditional development has drawn increasing attention from land use and environmental policy makers. It is argued that neighborhoods that are ‘compact’, or ‘transit-oriented’ can decrease automobile dependency, reduce air pollution, reduce the amount of land affected by impervious surfaces such as roads and parking lots, and reduce the consumption of agricultural land (Duany & Plater-Zyberk, 1992). The compact city is now widely accepted, particularly in land use planning policy, as the most effective solution to sustainable urban form. The compact city means high-density, mixed-use urban form. The claimed advantages of the compact city include conservation of countryside, less need to travel by car, thus reduced fuel emission, support for public transport and walking and cycling, better access to services and facilities, more efficient utility and infrastructure provisions, and revitalization and regeneration of inner urban areas (Burton[B], 2000). An increasing number of state and local governments have adopted new policies to encourage compact development in response to rising concerns about urban sprawl. In addition, for many planners and scholars, compactness is the crucial typology to be implemented to achieve sustainability. According to Dumreicher et al., a sustainable city should be compact, dense, diverse, and highly integrated. They suggest urban forms that are easily walkable, small enough to decrease the need for a private automobile, yet large enough to provide a variety of opportunities and services that constitute a rich urban life (Dumreicher et al., 2000). Moreover, related to transport, sustainable urban form must have a form and scale appropriate to walking, cycling, and efficient public transport. Compactness also encourages social interaction. It must enable access to facilities and services of the city while minimizing resulting external costs (Elkin et al., 1991). Cervero insists that compact, transit-oriented development shortens trips, thus encouraging non-motorized travel. Also, conversion of low-occupancy auto trips to mass transit cuts down per capita fuel consumption (Cervero, 1998). Some scholars argue that compact cities offer opportunities to reduce fuel consumption for traveling since work and leisure facilities are closer together (Newman, 1997). Compact cities are also favored because urban land can be resued, while rural land beyond the urban edge is protected. Ultimately, it is argued that a good quality of life can be sustained, even with high concentrations of people (Jabareen, 2006). Also related, density and dwelling type affect sustainability through differences in consumption of energy, materials, and land for housing, transportation, and urban infrastructure (Walker & Rees, 1997). High density and integrated land use not only conserve resources but provide for compactness that encourages social interaction (Jabareen, 2006). As well, the European Commission’s Green Paper strongly advocates the compact city, stating that it makes urban areas more environmentally sustainable and improves quality of life (Commission of European Communities, 1990).

However, the compact city also has its weaknesses. According to previous researcher, the compact city attempts to deliver sustainability in one package. Only when all these elements—connectivity, high-density, mixed land uses, accessibility and pedestrian walkability—are combined can they create synergy by developing a sustainable urban form (Song, 2005). Also, when the concept of the compact city is applied to existing rather than new urban fabric, it refers to the containment of further sprawl rather than the reduction of the present sprawl (Hagan, 2000). Arguments against the compact city imply the rejection of suburban and semi-rural living, neglect of rural communities, less green and open space, increased congestion, increased segregation, and less power for making local decisions (Frey, 1999, p. 25).

Nevertheless, the compact city model is supported for several reasons. First, compact cities are argued to be efficient for more sustinable modes of transport. Second, compact cities are seen as a sustainable use of land by reducing sprawl, land in the countryside is preserved and land in towns can be recycled for development. Third, in social terms, compactness and mixed use are associated with diversity, social cohesion, and cultural development. Some also argue that it is an equitable form because it offers good accessibility. Fourth, compact cities are argued to be economically viable because infrastructure, such as roads and street lighting, can be more cost-effective per capita. Also population densities are sufficient to support local services and businesses (Williams et al., 2000).

2.3 Un-Sustainable Urban Form : Sprawl

Across the nation, growing numbers of cities are discovering links between urban sprawl and a wide range of problems, from traffic and air pollution to central city poverty and the degradation of scenic areas. As more civic leaders take steps to ameliorate these costs, they increasingly need meaningful information about the characteristics, extent and consequences of sprawl (Ewing et al., 2002). According to the chronology in Urban Sprawl, William H. Whyte first used the term 'urban sprawl' in an essay in 1958. And now, in the 21st century, the dominant form of city living is based on the automobile and this form is called sprawl (Glaeser & Kahn, 2003). In research funded by 'Smart Growth America,' the definition of sprawl begins with an exhaustive review of the existing academic and popular literature. Researchers have identified sprawl as the process in which the spread of development across the landscape far outpaces population growth. The landscape sprawl creates has four dimensions: a population that is widely dispersed in low-density development; rigidly separated homes, shops, and workplaces; a network of roads marked by huge blocks and poor access; and a lack of well-defined, thriving activity centers such as downtowns and town centers. Most of the other features usually associated with sprawl—the lack of transportation choices, relative uniformity of housing options or the difficulty of walking—are a result of these conditions (Ewing et al.,2002). Following to Burchell et al., divided their analysis into three distinct categories of urban phenomena: spatial patterns, root causes, and main consequences of sprawl. They found that the spatial patterns of sprawl are low density; unlimited outward expansion; land uses spatially segregated; leapfrog development and widespread commercial strip development (see Figures 1-4). The causes of sprawl result from a lack of central ownership or planning and highly fragmented land use governance. Finally, the consequences of sprawl: transport dominance by motor vehicles; great variance in local fiscal capability; and reliance on filtering for low-income housing (Burchell et al., 1998). The conclusion is that sprawl either causes or is caused by patterns of exclusive land use, including separation of homes, work places, and conveniences, as well as income segregation among residential communities. As the mixture of uses in a community declines, travel time and distance for those who live or work there increase (Galster et al., 2001).

Figure 1 Low Density & Single Use Development

Figure 2 Un-Centered Strip Development

Figure 3 Scattered & Leapfrog Development

Figure 4 Sparse Street Network

Sources by (Ewing, Pendall, & Chen, 2002)

Also, according to Smart Growth America, the impacts of sprawl on quality of life are pervasive; particularly, sprawl creates higher rates of driving and vehicle ownership. This indicates that in relatively sprawling regions, cars are driven longer distances per person which adds up to millions of extra miles and tons of additional vehicle emissions. Also, this is not simply a matter of greater or lesser affluence; even controlling for income, households are more likely to bear the expense of additional vehicles in more sprawling areas. Second, sprawl increases levels of ozone pollution. The degree of sprawl is more strongly related to the severity of maximum ozone days than per capita income or employment levels. Third, the residents in a sprawl area have a greater risk of fatal accidents and are at greater risk of dying in a car crash. The higher death rates in more sprawling areas may be related to higher amounts of driving, or to more driving on high-speed arterials and highways as opposed to driving on smaller city streets where speeds are lower. Speed is a major factor in the deadliness of automobile crashes. Finally, sprawl regions have depressed rates of walking and alternative transport use. In more sprawling areas, people are far less likely to take the bus or train or walk to work (Ewing et al., 2002).

2.4 Measures of Sprawl

In recent years, a number of academics, advocates, and journalists have sought to define and measure sprawl. The term ‘sprawl’ is related to both sustainability and urban form. However, the definitions of sustainability and urban form are broad and the concepts related to each of them are complicated. Indeed, the definition of boundaries of sprawl areas is not clear. For this reason, many research case studies analyze metropolitan areas not a single city. Also, almost all these research dealt with only one or two indicators in their research. However, sprawl's characteristic is not simple and the complexity of sprawl cannot be interpreted by one or two variables. Thus, many indicators should be included in order to research the measurement of sprawl measurement comprehensively.

2.4.1 USA Today

The best-known effort may be *USA Today's* sprawl index published in 2001 which measured the proportion of the metropolitan population living outside the Census-defined urbanized area and the changes in that proportion over time. The USA Today index assigned a score to each of 271 metropolitan areas based on two density-related measures by two variables. First, the percentage of a metro area's population living in urbanized areas. For the years in question, the Census Bureau defined 'urbanized' as those parts of a metro with 1,000 or more residents per square mile. Second, change in the percentage of metropolitan population living in urbanized areas between 1990 and 1999. The advantage of the USA Today index is its simplicity which makes it easy to explain. On the other hands, the major disadvantage is its total reliance on density as an indicator of sprawl; density measured in a way that fails to distinguish between development at low suburban densities and development at high urban densities.

The result has been not only highly simplistic characterizations of urban sprawl, but also wildly different estimates of which regions have the worst sprawl. As a result of this research, Portland, Oregon, is ranked as the most compact region while Los Angeles appears to be very sprawling. In another, their rankings are essentially reversed. A third study characterizes certain Northeastern metros as very sprawling, while a fourth finds them to be relatively compact. There are only a few consistent performers such as Atlanta, which always appears to be among the most sprawling (Ewing et al., 2002).

2.4.2 Sierra Club

In the report titled ‘Sprawl: The Dark Side of the American Dream’, the Sierra Club ranked the degree of sprawl among U.S. metropolitan areas. They defined the sprawl as low-density development beyond the edge of service and employment which separates where people live from where they shop, work, recreate and educate, thus requiring cars to move between zones (Sierra Club, 1998). According to their research, based on population shifts from city to suburb, growth of land area vs. growth of population, time wasted in traffic, and loss of open space, metros were subjectively rated with the degree of sprawl. Their conclusion was that sprawl was defined not only by its characteristics but its effects. Among the metros which have over 1 million population, Atlanta, St. Louis, and Washington, D.C. were rated most sprawling. Among medium size metros, with population between 500,000 and one million, Orlando, Austin, and Las Vegas shared that distinction.

2.4.3 Galster et al.

With Galster and colleagues (2001) developed the most complex and multi-faceted sprawl index to date in their research article ‘Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept’. They characterized sprawl by eight dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed use, and proximity. The condition of sprawl was defined as a pattern of land use that has low levels in one or more of these dimensions. Variables representing causes and consequences of sprawl, such as fragmented governance and auto dependence, were explicitly excluded from the definition (Galster et al., 2001). As a result of this research, New York and Philadelphia raked as the least sprawling of the 13 and Atlanta and Miami as the most sprawling. The disadvantage of this research is its availability of only 13 areas (Ewing et al., 2002).

3. US SUSTAINABLE CITY RANKING

Many previous researches have been announced the ranking of cities based on the measured sprawl with their own method. In the other words, many cities ranked by the cities' sustainability. In this thesis, 2008 US sustainable city ranking of SustainLane is the reference of the sustainable city ranking. Cause, this ranking is based on 15 variables by social, environmental, and economic.

3.1 Introduction of SustainLane

Since 2005, the website of 'SustainLane' announced the city ranking of the 50 largest cities in the United States, perhaps the most complete report card on urban sustainability. This online community is where everyone can connect with people interested in sustainability, who post and discuss sustainability news and information and learn about sustainability. Also, this ranking includes sustainability indicators such as social, economy, and environment. The SustainLane US City Rankings focus on the many ways city policies and practices differ from one another and how that affects the people living in those places. Also, SustainLane gives people the resources they need in order to make choices that can make their lives healthier and more sustainable in terms of home, community, and the environment in general (The SustainLane, 2006). Based on US Census data, the 50 most-populous US cities were selected for this study. This ranking explains how quality of life and city economic and management preparedness are likely to fare in the face of an uncertain future (Sustainable Circles Corp., 2008).

Table 1 2008 US Sustainable City Ranking

2008 US Sustainability City Ranking					
R	City	R	City	R	City
1	Portland, OR	18	Albuquerque, NM	35	Charlotte, NC
2	San Francisco, CA	19	Atlanta, GA	36	Houston, TX
3	Seattle, WA	20	Kansas City, MO	37	Fresno, CA
4	Chicago, IL	21	San Jose, CA	38	El Paso, TX
5	New York, NY	22	Tucson, AZ	39	Fort Worth, TX
6	Boston, MA	23	Jacksonville, FL	40	Nashville, TN
7	Minneapolis, MN	24	Dallas, TX	41	Arlington, TX
8	Philadelphia, PA	25	Omaha, NE	42	Long Beach, CA
9	Oakland, CA	26	San Diego, CA	43	Colorado Springs, CO
10	Baltimore, MD	27	New Orleans, LA	44	Indianapolis, IN
11	Denver, CO	28	Los Angeles, CA	45	Virginia Beach, VA
12	Milwaukee, WI	29	Louisville, KY	46	Memphis, TN
13	Austin, TX	30	Columbus, OH	47	Las Vegas, NV
14	Sacramento, CA	31	Detroit, MI	48	Tulsa, OK
15	Washington, DC	32	Phoenix, AZ	48	Oklahoma City, OK
16	Cleveland, OH	33	San Antonio, TX	50	Mesa, AZ
17	Honolulu, HI	34	Miami, FL		*R=Ranking*

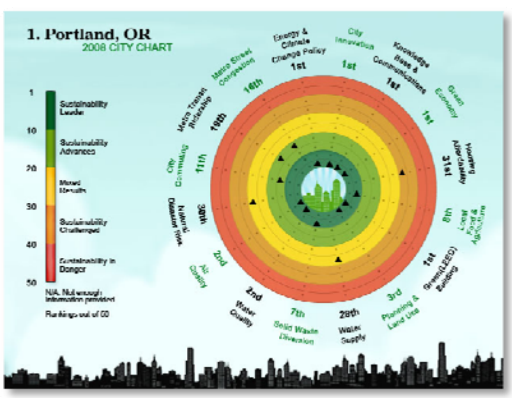

Figure 5 Portland, OR City Chart

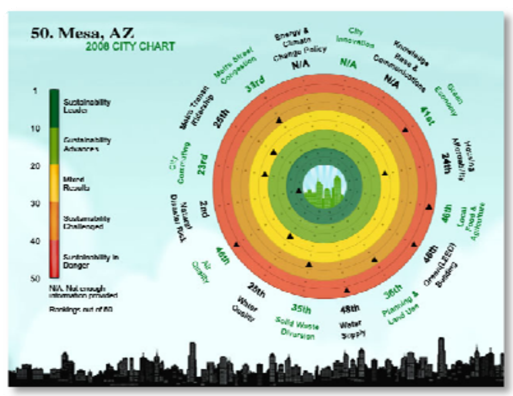

Figure 6 Mesa, AZ City Chart

Source by SustainLane

According to this ranking, Portland is most sustainable city in US and Mesa is most un-sustainable city in the U.S. (see Table 1). Figure 5 is the result of Portland's sustainability and Figure 6 is the result of Mesa's sustainability. Compared these two cities, almost all indicators of Portland are in the green level but only one indicator of Mesa is in the green level (see Figures 5 and 6). The reason for using this ranking is that this ranking includes 15 different indicators that represent various aspects of urban planning and sustainability. This thesis uses the 2008 US sustainability city ranking as the reference for the comparisons and analyses of indicators. Among them, some are related to urban form but the others are not. Throughout the statistical analysis using SPSS, this thesis research analyzed which indicators have correlations with sustainable city ranking and how strong the correlation is. After that, related urban form indicators are decided and those indicators are analyzed and compared based on the literature review. Figure 7 is the result of SustainLane's 2008 US sustainable city ranking. The red spots, they are ranked top to 10th cities, are most sustainable cities and the purple spots, they are ranked bottom to 41st cities, are most un-sustainable cities among the 50 US cities. According to Figure 7, most sustainable cities are located nearby east and west coastal area and Lake Michigan. On the other hands, most un-sustainable cities are generally located in inland, except a few cities such as Virginia Beach and Long Beach. In addition to, when divide by south and north to the United States by directionally, the north area have many sustainable cities than south area. Particularly, in the top ten cities are located in north area (see Figure 7).

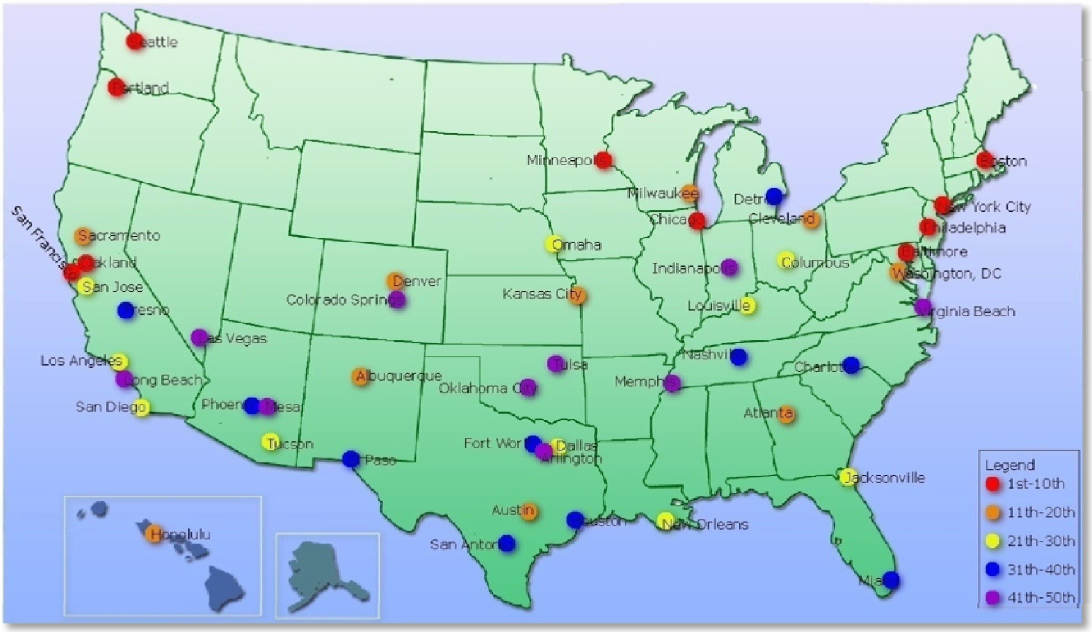

Figure 7 2008 US Sustainable Cities Overall Ranking

3.2 Methodology

The basic concept of sustainability combines environmental, economic, and social issues. Based on this concept, SustainLane US City Rankings were developed using a combination of data and information. They are drawn from surveys and interviews, and publicly available published sources. Overall rankings were determined by averaging 15 individual indicator rankings. Based on 2004 US Census data, the 50 most-populous US cities were selected for this research. The SustainLane 2008 US sustainable cities overall rankings were determined by averaging 15 individual indicators rankings, each of which was multiplied by a weighting of their score. Of the 15 indicators, 11 received a weighting of 1.0 Water Supply, Commute to Work, Congestion, Housing Affordability and Natural Disaster Risk each receive weights other than 1.0.

Among these, Water Supply and Commute to Work were weighted as 1.5 because these two are increasingly crucial issues. The other three, Congestion, Housing Affordability and Natural Disaster Risk, are weighted as 0.5 because these impacts are of a secondary nature (Sustainable Circles Corp., 2008).

3.3 Data Collection

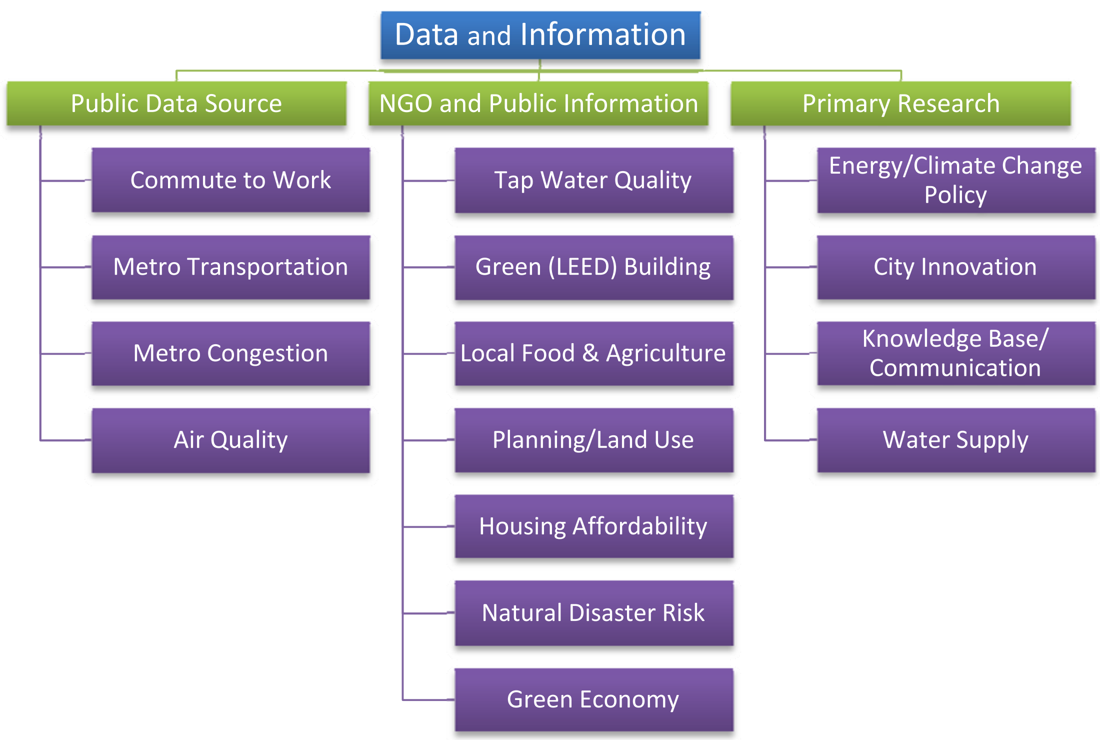

Figure 8 SustainLane 2008 US Sustainable City Ranking Data Categories

SustainLane US sustainable city ranking result includes 15 different indicators (see Figure 8). Data sources are divided into three categories—Public Data Source, NGO and Public Information, and Exclusive SustainLane Primary Research. Primary research consisted of email and phone surveys administered to the 50 subject cities.

City contacts included environmental or sustainability departments, energy offices, departments of public works and solid waste, water departments, mayors' offices and planning departments. Non-Governmental Organizations (NGOs) working directly with subject cities were also surveyed or interviewed. A total of 45 cities responded to the survey. For the cities that did not respond to the survey, rankings were determined by data from public and non-governmental data sources only. Data was adjusted on a per capita basis for local food and agriculture as well as for green (LEED) buildings. In total, over 100 respondents were surveyed by email or telephone, or were interviewed in person. A list of these people and their city or organizational affiliations is available upon request from SustainLane. Data was collected on a city-basis except for four categories, due to availability. Regional public transit ridership, roadway congestion, and metro area sprawl data were collected on a metropolitan area basis. Air quality data was gathered on a county-wide basis (Sustainable Circles Corp., 2008).

- Public Data Sources

Public data from the most current sources were combined in each indicator: Commute to Work, Metro Transportation, Metro Congestion, and Air Quality are included in this category (see Table 2).

Table 2 SustainLane Public Data Source

Indicator	Source	Unit
Commute to Work	The US Bureau The Census/American Fact Finder	Percentage of Public transportation ridership, walk-to-work, bike-to-work, carpool-to-work, and drive-alone-to-work
Metro Transportation	Texas Transportation Institute's 2007 Urban Mobility Study	Based on metro region public transit ridership miles and square miles per region
Metro Congestion	Texas Transportation Institute's 2007 Urban Mobility Study.	Average time spent waiting in traffic
Air Quality	US EPA air quality data Information Median Air Quality Index Combined with US EPA Clean Air Act Non-Attainment information	Average Air Quality Indexes along with EPA data on Clean Air Act Non-Attainment areas

The contents of Commute to Work are percentage of public transportation ridership, walk or bike to work, and carpool or drive-alone to work. The data of Metro Transportation and Metro Congestion is from the Texas Transportation Institute (TTI)'s urban mobility study. Related to transportation, Air Quality is the last indicator in this category. The data of Air Quality is from US EPA. Among these indicators, Commutes to Work and Metro Congestion are related to sustainable urban form. These two indicators are analyzed in the next section.

- NGO and Public Information

In Non-Governmental Organization (NGO) and Public Information category, Tap Water Quality, Green (LEED) Building, Local Food & Agriculture, Planning/Land Use, Housing Affordability, Natural Disaster Risk, and Green economy are included (see Table 3). Tap water quality's data is from environmental working group's city drinking water database. Green (LEED) building is based on data from the US Green Building

Council's Leadership in Energy and Environmental Design rating system. Local Food & Agriculture's data is from the US Department of Agriculture. Also, Planning and Land Use data from Smart Growth America's research and Trust for Public Land for percent of city land area devoted to parks. US Census Bureau data, throughout median housing price and incomes, were used to analyze Housing Affordability. The Natural Disaster Risk is based on the risk of hurricanes, major flooding, catastrophic hail, tornadoes and earthquakes.

Table 3 SustainLane NGO and Public Information Source

Indicator	Source	Unit
Tap Water Quality	Environmental Working Group's city drinking water database, "National Assessment of Tap Water Quality." from state water offices.	
Green (LEED) Building	Number of US Green Building Council's LEED certified. Registered buildings from US Green Building Council.	Adjusted per capita LEED Platinum or Gold vs. Silver or Certified
Local Food & Agriculture	NGOs & the US Department of Agriculture	Number of community gardens Number of farmers markets per city
Planning & Land Use	Urban sprawl data from Smart Growth America's study.	Percent of city land area devoted to parks came from Trust for Public Land 2007 SustainLane primary research
Housing Affordability	US Census Bureau data	Median US housing prices Median US incomes
Natural Disaster Risk	Risk Management Solutions' 1999 Catastrophic Risk in the United States' SustainLane primary research	Cumulative measure of hurricane risk, flood risk, tornado super outbreaks, earthquake risk, and devastating hail risk
Green Economy	USGBC & SustainLane Primary research	Clean technology incubator Green business activity Local/farmers markets per capita LEED buildings per capita data

Also, Green Economy indicator scores by farmers' markets per capita. Among these indicators, only the indicator 'Planning and Land Use' is linked with sustainable urban form. SustainLane's research on Planning and Land Use used three different data; SGA's study and SustainLane primary research. However, in this thesis, only related with urban form data from Smart Growth America's study is included; mixed land use, centeredness and street connectivity.

- Exclusive SustainLane Primary Research

Data of Exclusive SustainLane Primary Research's categories are; Energy and Climate Change Policy, City Innovation, Knowledge Base and Communications, and Water Supply (see Table 4). Energy and Climate Change Policy is the percentage for each city's alternative fueled vehicles as part of the total vehicle fleet. Also, it is representative of carbon emission and renewable energy use.

Table 4 Exclusive SustainLane Primary Research Source

Indicator	Category	Unit
Energy and Climate Change Policy	City greenhouse gas tracking and carbon emission inventories Carbon emission reduction goals Overall use	Percentage for each city's alternative fueled as part of the total vehicle fleet
City Innovation	Environmentally preferable purchasing programs City commercial green building incentives City residential green building incentives Carpooling coordination and Car sharing programs (public or private)	
Knowledge Base & Communication	Whether the city has an overall plan for sustainability Whether it has a sustainability or environmental department that manages and tracks sustainability efforts across the city Whether the city is working in collaboration with a major federal research laboratory or research university Whether the city is working with a non-governmental organization across the city, rather than in only a single neighborhood	
Water Supply	Distance in miles from primary source of untreated drinking water, Dependence of water on snowpack, level of drought or other conflict	Gallons of water consumed per person per day

If the city has an environmental friendly program, the city is scored in the City Innovation category. Knowledge Base and Communication was analyzed by whether the city has an overall plan for sustainability and city effort to education for sustainability.

The last indicator, Water Supply, is for desert cities and cities hundreds of miles away from their fresh water sources. It includes water dependence on snowpack, level of drought or other conflicts and gallons of water consumed per person per day.

Of these 15 indicators, only 3are related to urban form— Commute to Work, Metro Congestion, and Planning and Land Use. According to literature review, the indicators of density and mean travel time to work are added to enhance of the analysis. The data of density and mean travel time to work are based on the U.S. Census Bureau/American Fact Finder Data. These indicators are compared with the SustainLane's sustainable city ranking result.

3.4 Correlation between Overall Ranking and Each Indicator

In this section, using the Statistical Package for the Social Sciences (SPSS), I analyze the relationship between SustainLane overall ranking and their indicator. The tool of a Pearson Correlation Coefficient is used in the relationship analysis between overall ranking and the ranking of each indicator. This research expects that every single indicator has a correlation with overall ranking. To demonstrate this correlation, I establish a null hypothesis and an alternate hypothesis. The alternate hypothesis is that:

H_1: Each indicator has a correlation with overall ranking.

As the result shows the indicator of Metro Street and Freeway Congestion, Natural Disaster Risk, Tap Water Quality and Water Supply' p-values are higher than 0.05. It concludes that the correlations between these four indicators and SustainLane overall ranking are not significant at the 0.05 level (see Table 5).

Table 5 Correlation between Overall Ranking and SustainLane Each Indicator

Indicator	Overall Ranking		Indicator	Overall Ranking	
	Pearson Correlation	Sig. (2-tailed)		Pearson Correlation	Sig. (2-tailed)
Air Quality	0.317	0.025	Local Food & Agriculture	0.739	0.000
City Commuting	0.752	0.000	Metro Street & Freeway Congestion	-0.146	0.313
City Innovation	0.763	0.000	Metro Public Transit Ridership	0.512	0.000
Energy and Climate Change	0.599	0.000	Natural Disaster Risk	-0.030	0.838
Green Building	0.684	0.000	Waste Management	0.447	0.001
Green Economy	0.857	0.000	Tap Water Quality	0.086	0.576
Housing Affordability	-0.459	0.001	Planning & Land Use	0.551	0.000
Knowledge Base & Communications	0.594	0.000	Water Supply	0.146	0.312

However, except these four indicators—Metro Street and Freeway Congestion, Natural Disaster Risk, Tap Water Quality and Water-Supply— other indicators' p-values are smaller than 0.05. It means that there is a statistically significant relationship between each indicator's ranking and overall ranking. The indicator which has the strongest correlation with the overall ranking is Green Economy. Next indicators are City Commuting, City Innovation and Local Food and Agriculture also show a strong correlation with overall ranking (see Table 5). The indicator of Housing Affordability shows negative correlation with overall ranking. The indicator of Housing Affordability is including an average housing prices and an average income levels data. This result shows that sustainable city's housing prices is cheap than un-sustainable city's housing prices. Related with Housing Affordability, this research is going to be the future work.

The indicators which are related with urban form, such as City Commuting, Metro Public Transit Ridership, and Planning and Land Use, illustrate that they have a correlation with overall ranking; all of r-value is higher than 0.3. According to this reason, this research expects that high ranking cities, on the other words, sustainable cities, have a sustainable urban form such as compact city.

3.5 Remarkable Point of Ranking

By the overall SustainLane ranking, Portland, Oregon is the most sustainable city in the US in 2008. On the other hand, Mesa, Arizona is the most un-sustainable city in the US city ranking. Indeed, looking into this result, I found a remarkable point throughout SutainLane's ranking result which is related with urban form. This interesting point is the cities' development era. According to SustainLane, based on when the majority of each city's development occurred, the cities are divided into two groups.

Table 6 Pre-1945 vs. Post-1945

1-10	11-20	21-30	31-40	41-50
Portland, OR	Denver, CO	San Jose, CA	Detroit, MI	Arlington, TX
San Francisco, CA	Milwaukee, WI	Tucson, AZ	Phoenix, AZ	Long Beach, CA
Seattle, WA	Austin, TX	Jacksonville, FL	San Antonio, TX	Colorado Springs, CO
Chicago, IL	Sacramento, CA	Dallas, TX	Miami, FL	Indianapolis, IN
New York, NY	Washington, DC	Omaha, NE	Charlotte, NC	Virginia Beach, VA
Boston, MA	Cleveland, OH	San Diego, CA	Houston, TX	Memphis, TN
Minneapolis, MN	Honolulu, HI	New Orleans, LA	Fresno, CA	Las Vegas, NV
Philadelphia, PA	Albuquerque, NM	Los Angeles, CA	El Paso, TX	Tulsa, OK
Oakland, CA	Atlanta, GA	Louisville, KY	Fort Worth, TX	Oklahoma City, OK
Baltimore, MD	Kansas City, MO	Columbus, OH	Nashville, TN	Mesa, AZ
				Red = Pre-1945

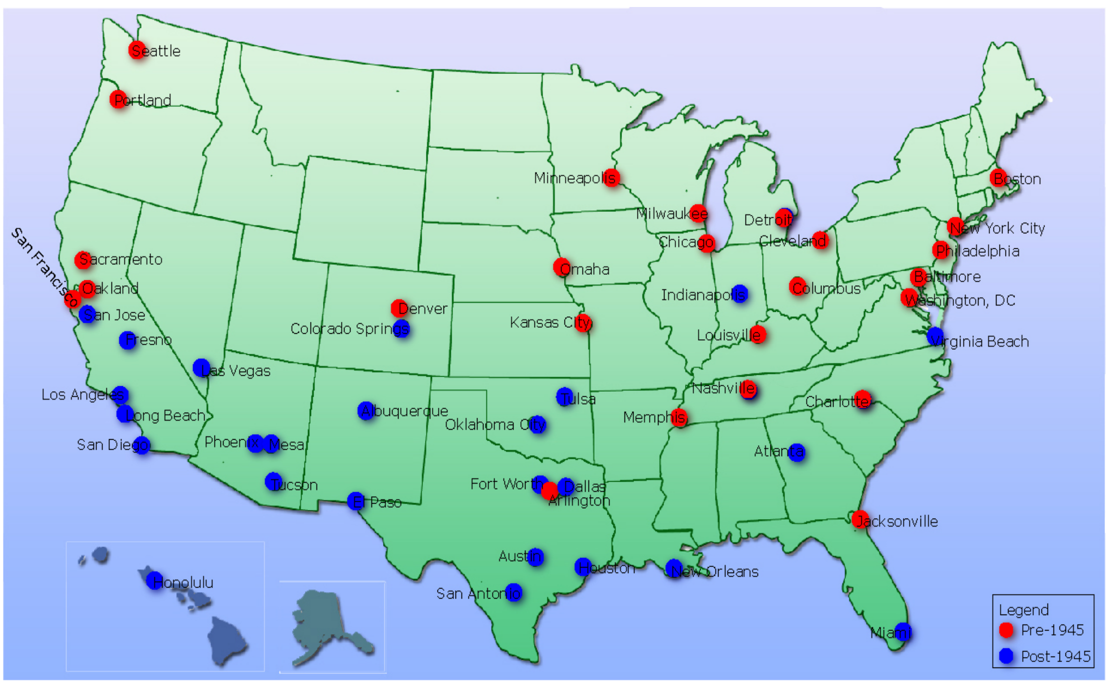

Figure 9 Development Age of City

That is cities by age of primary development before 1945 or after 1945; 1945 means after World War II, and primary development indicates whether the city has a comprehensive or development plan related to sustainability (see Figure 9 and Table 6).

All of the 50 cities were founded and incorporated in the 1800s, but the development planning and major development occurred at a later time. Table 6 indicates that high ranked cities developed before 1945 and low ranked cities developed after 1945 cities. All cities, ranked in the top ten, are developed before 1945. However, city ranking is going down, developed before 1945—the boxes shaded in red indicate cities which developed before 1945 (see Table 6). Except for a few cities such as Arlington, Atlanta and Indianapolis, the ranking result can be organized according to South and North (see Figure 7). The red spots on the map in Figure 7 are the cities which developed before 1945 and the blue spots are the cities which developed after 1945.

According to SustainLane, 20^{th} century urban form draws heavily on 19th century planning philosophies. Urbanism is deeply rooted in social and political theory. As time progressed and theories changed, so did planning practices. City planning has long been used for hegemonic displays, as a tool to subvert marginalized populations, and as a way to provide for the health and well-being of its residents. Urban form simultaneously reflects society and directs it. For example, high density urban life was perceived as the source of crime and disease, and the answer was wide open spaces and country living (Sustainable Circles Corp., 2008). Arguably, one of the most influential urban planning theories in the United States comes from Ebenezer Howard, a turn-of-the-century British planner who conceptualized the 'Garden City'. Under Howard's plan, people would live in satellite communities located away from large cities which housed industry and commerce. In Howard's theory, city life benefited from jobs, social opportunity, and entertainment, but suffered from poor air quality and slums. In contrast, the country offered cheap rent and ample space, but low wages and a lack of public spirit. Combining the two created an idyllic place, featuring all the pros of each, and none of the cons. Today's suburbs are grim adaptations of Howard's garden cities. Instead of garden cities, they are garden suburbs, as modeled by Frederick Law Olmsted in the late 19th century. Highways, freeways, and multi-lane thoroughfares replace Howard's railways as a way to connect communities in the twentieth century American model. Many American cities do not have ample green-space to relax in or easily accessible and well-maintained neighborhood parks, trails, or community gardens. One of the most pronounced shifts in American city planning coincided with the end of World War II. Traditional urban development, as found in nearly every city built by man—street grids, mixed-use buildings, districts, and vibrant downtowns—gave way to suburban development—tract housing, strip malls, and low density. As a result, cities built up in the latter half of the twentieth century were car-oriented; people traveled farther for goods and services they needed at the mega malls and big-box stores found on the fringes of many communities. Residents in these communities drive to work, drive to school, drive to eat, drive to entertainment. A dependence on driving increases social isolation and exacerbates health problems including obesity and heart disease. Cars pollute our environment, their exhaust degrades air quality and urban runoff from roads and freeways pollutes watersheds and groundwater supplies. Streets are unsafe to play in. And they're noisy. And finally, cars are dangerous. Beside, cities with a car-oriented tradition likely won't have strong on as many practical options. Post-1945 suburban development is synonymous with sprawl, a key factor in Planning and Land Use

(Sustainable Circles Corp., 2008). To reduce automobile dependence, a city needs to increase public transit ridership and promote multi-modal transportation and a plan for people to live within walking distance of their day to day needs. Also, increased use of Transit Oriented Development (TOD) is necessary to create downtowns around train and bus stations where people can live, work and shop in easily accessible locations. In the next section, I will analyze and compare the ranking result related with the above accessibility.

4. URBAN FORM INDICATOR ANALYSIS

According to Section 2 Literature Review and section 3.4 Correlation between Overall Ranking and Each Indicator, in this section, the SustainLane's overall ranking and four categories related with urban form indicators ranking are analyzed and compared by 1) density, 2) mode of commute to work, 3) mean travel time to work & traffic congestion cost, and 4) planning & land use. Analytical method: first, establish a hypothesis for each indicator. Second, following SustainLane data source, collect raw data which is only related with urban form. Third, using these raw data, analyze 50 cities and then remake new ranking in accordance with the raw data and each indicator. Fourth, compare with overall ranking and new ranking from analysis. Last, determine if the null hypothesis is rejected or not. Each indicator's hypothesis is based on the following suppositions;

1. *'High ranking cities are sustainable cities'.*
2. *'Sustainable city has a sustainable urban form.'*
3. *'Sustainable urban form is a compact city form.'*

Following a syllogism, the conclusion is that

'High ranking cities have a compact city form'.

To improve this logic, a null hypothesis and alternate hypothesis for each indicator are established—density, mode of commute to work, mean travel time to work & traffic congestion cost, and planning & land use. These indicators represent compact city form. The compact city has a variety of definitions but in general is taken to mean a relatively high-density, strong mixed-use, short VMT and cheap congestion cost, urban settlement based on an efficient public transport system and dimensions that encourage walking and cycling. It contrasts with the car-oriented ‘urban sprawl’ of many modern towns and cities (Burton[A], 2000). The characterizes of the sprawl are low density, auto-dependent land development taking place on the edges of urban centers transforming open undeveloped land into single-family residential subdivisions and campus-style commercial office parks with diffuse retail uses (Soule, 2006). Henceforth, in this thesis, the meaning of sustainable urban form is same as compact city and un-sustainable urban form is same as sprawl.

4.1 Density

The population density is a critical indicator in determining sustainable urban forms (Jabareen, 2006). The definition of population density is a measurement of population per unit area or unit volume. High density is the most representative characteristic of compact city. Many researchers have investigated the relationship between density and car dependency in cities worldwide and found that density is a major explanatory variable for the level of transport energy use. There are also cost savings for public transport associated with higher densities. Hence certain strategies will be beneficial, such as nodes and corridors of high density development, revitalizing inner cities, focusing development around the existing rail system, discouraging further sprawl, and developing public transport in combination with developing new villages in the suburbs (Newman & Kenworthy, 2000). Thus, the expected result is that high ranked cities have higher density than low ranked cities because high ranking cities are more sustainable than low ranking cities. Therefore, the null hypothesis and alternate hypothesis would be:

H_2: High ranking cities are correlated with high density.

To test this hypothesis, I look at the U.S. Census Bureau data comparing the density of 50 cities. However, the 2008 US Census Bureau does not contain the Louisville population, so Louisville population is founded the population data in the web site of Kentucky State. Also, the boundary of population is the city, which is defined as a type of incorporated place in 40 states and the District of Columbia. In 23 states and the District of Columbia, some or all cities are not part of any Minor Civil Division (MCD), and the Census Bureau also treats these as county subdivisions, statistically equivalent to MCDs. It is a primary governmental and/or administrative subdivision of a county, such as a township, precinct, or magisterial district. MCDs exist in 28 states and the District of Columbia. In 20 states, all or many MCD's are general-purpose governmental units: Connecticut, Illinois, Indiana, Kansas, Maine, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, and Wisconsin. Most of these MCD's are legally designated as towns or townships (U.S. Census Bureau, 2007).

Table 7 Correlation between SustainLane Overall and Density Ranking

	Overall Ranking	
Density	Pearson Correlation	.598
	Sig. (2-tailed)	.000
	N	50

As a result of the relationship between overall ranking and density ranking by SPSS, p-value is lower than 0.05 and r-value is 0.598 (see Table 7). There is a statistically significant relationship between density and overall ranking and, according to r-value, the relationship is strong. Thus, the hypothesis that high ranking cities are not correlated with high density is rejected. It means that high ranking cities have a high density. Compared with the overall ranking, like the SPSS correlation result, high ranking cities have a high density (see Table 8 and Appendix A).

Table 8 City Ranking by Density

Ranking		City	Ranking		City	Ranking		City
O	D		O	D		O	D	
5	1	New York	14	18	Sacramento	18	35	Albuquerque
2	2	San Francisco	37	19	Fresno	22	36	Tucson
6	3	Boston	17	20	Honolulu	38	37	El Paso
4	4	Chicago	47	21	Las Vegas	35	38	Charlotte
34	5	Miami	1	22	Portland	39	39	Fort Worth
8	6	Philadelphia	19	23	Atlanta	46	40	Memphis
15	7	Washington	26	24	San Diego	44	41	Indianapolis
42	8	Long Beach	11	25	Denver	48	42	Tulsa
28	9	Los Angeles	41	26	Arlington	43	43	Colorado Springs
10	10	Baltimore	36	27	Houston	45	44	Virginia Beach
9	11	Oakland	25	28	Omaha	27	45	New Orleans
3	12	Seattle	24	29	Dallas	29	46	Louisville
7	13	Minneapolis	30	30	Columbus	20	47	Kansas City
31	14	Detroit	50	31	Mesa	40	48	Nashville
12	15	Milwaukee	33	32	San Antonio	23	49	Jacksonville
16	16	Cleveland	32	33	Phoenix	49	50	Oklahoma City
21	17	San Jose	13	34	Austin	*O = Overall / D = Density*		

The highest density city is New York (27,440 pop/sq mi) and the lowest city is Oklahoma City (909 pop/sq mi). The density of New York is 30 times denser than Oklahoma City. Also, Oklahoma City is only one city which's density is lower than a thousand person per square mile. Only consider the top and the bottom density city, high ranking city has a high density as like New York and low ranking city has a low density as like Oklahoma City. It means sustainable city has a high density and un-sustainable city has a low density. Thus, high ranking city is sustainable city and have a compact city characteristic about density. The next highest density city is San Francisco (17,322.8 pop/sq mi) and third highest density city is Boston (12,575.3 pop/sq mi). In the density ranking, the most moved up city is a Long Beach whose overall ranking was 42^{nd} but whose density ranking is 8^{th}. That means Long Beach is not a sustainable city even though it has a high density. By contrast, Kansas City was 20^{th} in overall ranking but by density alone the city ranked 47^{th}. Kansas City is moved down to the 27^{th} ranking.

According to Lynch's (1954) article, titled 'The Form of Cities', when the density is lower than 1,000 persons per square mile, it would be the density of community of single-family houses on lots of an acre or more. In this density analysis, Oklahoma City is included in this range. Indeed, 3,500 persons per square mile of density is the typical U.S. suburban area with single houses on generous lots. This is the American dream becoming reality: a home of one's own, a measure of privacy and freedom, room for children to grow in. In the density result, Columbus (3,589.6 pop/sq mi) and Mesa (3,487.2 pop/sq mi) are included in this range. These two cities ranked by 30^{th} and 31^{st} in the density ranking. Also, at 10, 000 persons per square mile becomes an urban structure in which the dominant residential type is group housing instead of single family housing: row houses, two-family houses and the like. The cities which are included in this range are Miami (11,580.7pop/sq mi), Philadelphia (11,361.0 pop/sq mi), Long Beach (9,275.8 pop/sq mi), and Washington (9,639.0pop/sq mi). All these four cities ranked in top ten high density cities. Besides, at 35,000 persons per square mile people live walk-up apartments three and four stories high. It spells a more difficult environment for, growing children, a surrender of light and air. Yet there are also positive values: better social intercourse, a strong feeling of "urbanity," short journeys to work or to the open country, efficient mass transportation. New York (27,440 pop/sq mi) is included in this range.

Most of the top-ranked cities show high density (see Figure 10). Among the top ranked cities, New York and San Francisco show extremely high density. However, ranked cities in the top ten, Seattle, Minneapolis, Oakland and Baltimore exhibit the density level of just over a 5,000 persons per square mile. Particularly, the top city, Portland’s density is lower than 5,000 persons/square mile. Oppositely, among low ranked cities, the densities of Washington, Los Angeles, Detroit, Miami and Long Beach are much higher than other cities. On the other hands, an interesting point is that the high density cities are located near coastal area or huge lake. This result is same as above the development age analysis result. The result of density demonstrates that the density is becoming decreased even though the graph is not reflecting the overall ranking result directly. Also, the SPSS result shows that density and sustainable city has a strong correlation.

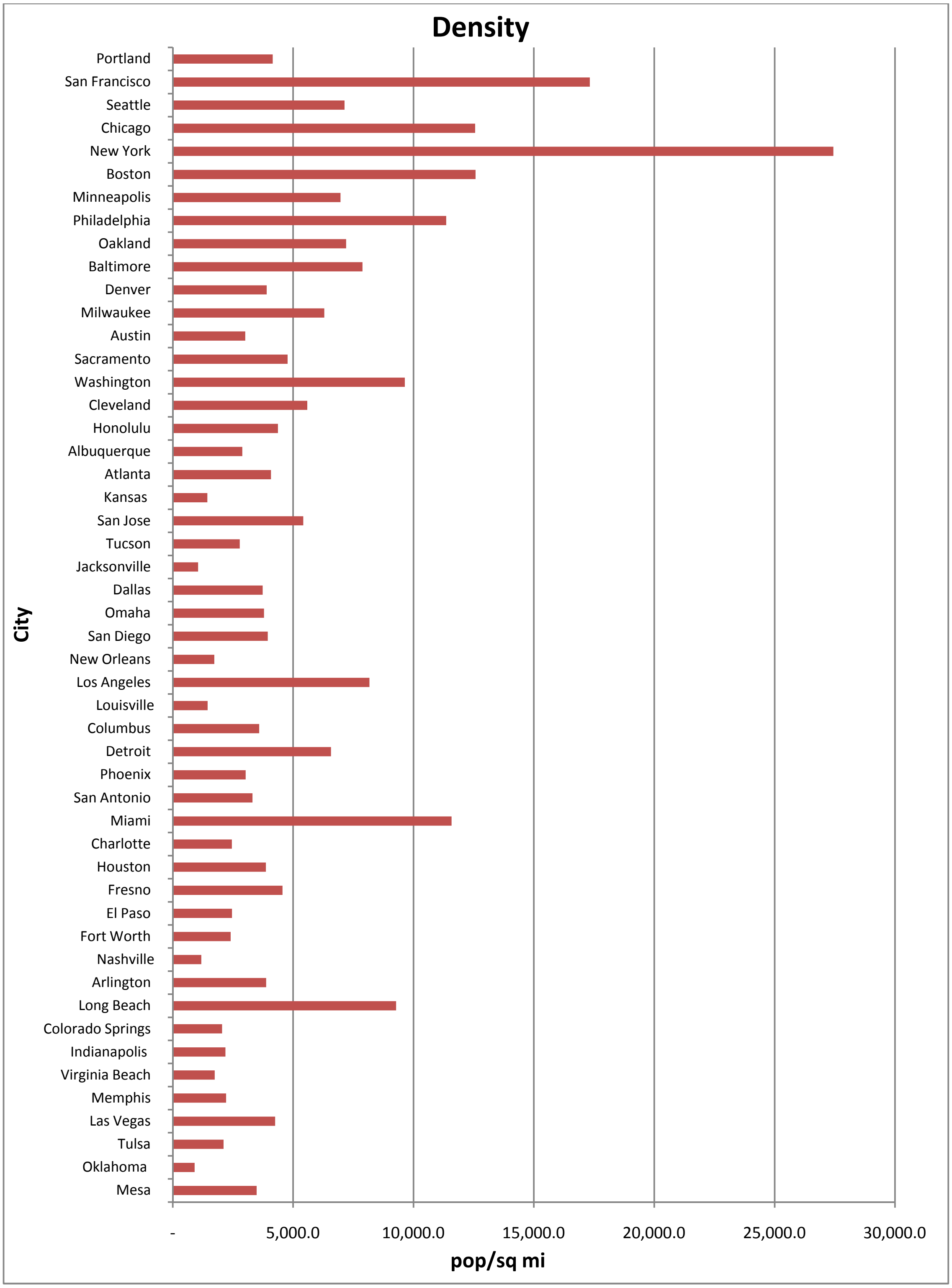

Figure 10 Density

Thus, high ranking cities have a high density and it is one of the characteristic of compact city form. Therefore, only considering density, high ranking cities have compact city form. In addition, high density cities are generally located nearby ocean or huge lake, especially in the east and west coastal areas.

4.2 Mode of Commute to Work

Even though changing socio-economic conditions increase the flexibility of the workforce such as home workers that are believed to internalize the need for home-work space in their housing consumption, many productions in a city occurs at a point, the central business district (CBD). In the morning, people go to work and in the evening they come back home. People must often commute long distances as only a few are connected to job centers by transit (Neuman, 2005). Individual commuters increase the social costs of congestion by their use of road networks, which leads to excessive commuting and cities that are too large. Like this, the commute to the city center also one of the reasons for sprawl, with cities built around public transportation tend to be more compact than cities built around the automobile (Burchfield et al., 2006). In addition to reducing energy use and traffic congestion by using public transportation, people travel less because land development and use is more efficient where there is transit service. In total, public transportation reduces gasoline use by 4.2 billion gallons annually (Americal Public Transportation Association, 2008). As sprawl increases, so do the number of miles driven each day (daily vehicle-miles traveled, or DVMT); the number of vehicles owned per household; the annual traffic fatality rate; and concentrations of ground-level ozone, a component of smog. At the same time, the number of commuters walking, biking or taking transit to work decreases to a significant extent (Ewing, Pendall, & Chen, 2002). According to this trend, the hypothesis about the mode of commute to work is:

H_3: High ranking cities and sustainable mode of commute to work have a positive correlation.

To test this hypothesis, the data of percentage of public transportation, drive-alone-to-work, carpool, walking, bicycling, and motorcycle were analyzed. The data of these were from the 2007 American Community Survey in the U.S. Census Bureau. Also, the walking score by the web-site of Walk-Score was added in this analysis. According to each category's percentage, I will make a new ranking and then compare with the original overall ranking. The U.S. Census Bureau data is the percent of workers 16 years and over who travel to work by car, truck, or van. The public transportation excludes taxicabs and Louisville's walking, bicycling and motorcycling data is not included in the U.S. Census Bureau. Thus, Louisville ranking is included by only percentage of public transportation, drive-alone-to-work from the U.S. Census Bureau and walking score from Walk-Score web-site. A result of mode-of-commute-to-work and overall ranking's relationship by SPSS is that all modes of p-value are lower than 0.05, except motorcycling (see Table 9). Thus, there is a statistically significant relationship between overall ranking and mode of commute to work, except motorcycling. In addition to, except motorcycling, all modes show strong relationship with overall ranking. The r-values of drive alone variable is 0.743; drive alone has most strong relationship with the overall ranking. Next variable is walking and public transportation as 0.724. The meaning of this result is that high ranking cities' people are more using public-transportation, bike and walking when their commute way.

Table 9 Correlation between SustainLane Overall and Mode of Commute to Work Variables Ranking

	Overall Ranking		
	Pearson Correlation	Sig.(2-tailed)	N
Walking	0.724	0.000	49
Bicycling	0.521	0.000	49
Motorcycling	0.196	0.178	49
Walk-score	0.660	0.000	50
Drive-alone	0.743	0.000	50
Public Transportation	0.724	0.000	50
Carpool	-0.421	0.002	50

Moreover, low ranking cities' people prefer to drive-alone on their commute way. In the drive-alone and overall ranking analysis, low percentage of drive alone city got a high ranking. Thus, hypothesis that high ranking cities and sustainable mode of commute to work such as public transportation, walk, and bike do not have a correlation is rejected. As well, high ranking cities have a characteristic of compact city form about mode of commute to work such as walk, bicycling and public transportation.

However, about the carpool variable, the p-value is lower than 0.05 but r-value is negative 0.421. It means that carpool has a negative relationship with overall ranking. Because in this analysis, high ranked cities carpool percentage is small. Thus, low ranking cities' people are more using carpool than high ranking cities' people. To figure out this result's reason, the relationship with carpool and other modes are analyzed. As a result of SPSS, carpool has a negative correlation with all other modes (see Table 10). In the carpool ranking, low percentage of carpool city got a high ranking. Among these, public transportation, walking and walk-score has statistically significant relationship with carpool. All of these three modes' p-values are lower than 0.05 and r-values around -0.4. It means that the large percentage of using carpool city has small percentages of using public transportation and walking. Also, the large percentage of cities in which commuters use a carpool has a low walk-score. It explains that people in the low walk-score cities' is difficult to walk and use public transportation. Therefore, people use their own car. That is the reason of carpool's negative result. Thus, low ranking cities' people more use carpool because they believe it is not easy to use public transportation or to walk on their commute.

Table 10 Correlations between Modes of Commute to Work and Carpool

		Drive-alone	Public-transportation	Walking	Bicycling	Walk-score
Carpool	Pearson Correlation	-.228	-.400	-.397	-.055	-.400
	Sig. (2-tailed)	.112	.004	.007	.705	.004
	N	50	50	49	49	50

According to these results, without motorcycling variable, new ranking by mode of commute work is made by each variable's average ranking result. With SustainLane overall ranking, the mode of commute to work new ranking has a strong correlation (see Table 11). It means that, in the SustainLane overall ranking, high ranked cities' people more use public transportation, walk, and bike in their commute to work way. Also, high ranked cities in the SustainLane walk score are higher than low ranked cities. Thus, people prefer to walk and use public transportation.

Table 11 Correlation between SustainLane Overall and Mode of Commute to Work New Ranking

	Overall Ranking	
Mode of Commute to Work New Ranking	Pearson Correlation	.712
	Sig. (2-tailed)	.000
	N	50

In the mode of commute to work ranking, the top city is San Francisco and the next city is Honolulu. Boston is the 3rd city. On the other hand, the bottom city is Virginia Beach (see Table 12). Following Virginia Beach, Indianapolis is 49th and Louisville is the 48th ranked city. Generally, the cities which were the top level in overall ranking show also high ranking in the result of Mode of Commute to Work too. In the mode of commute to work ranking, the most moved up city is Mesa, Arizona. This city was the last city in overall ranking but it is the 21st city in the new ranking, up 29 places in the ranking. Oppositely, the most moved down city is Kansas City. In the overall ranking, Kansas City was 20th but in the new ranking, it is 47th. Kansas City is falls 27 places.

Table 12 The Mode of Commute to Work New Ranking

Ranking		City	Ranking		City	Ranking		City
O	M		O	M		O	M	
1	9	Portland	18	23	Albuquerque	35	38	Charlotte
2	1	San Francisco	19	29	Atlanta	36	26	Houston
3	5	Seattle	20	47	Kansas City	37	32	Fresno
4	8	Chicago	21	30	San Jose	38	44	El Paso
5	12	New York	22	16	Tucson	39	43	Fort Worth
6	3	Boston	23	45	Jacksonville	40	46	Nashville
7	4	Minneapolis	24	33	Dallas	41	35	Arlington
8	10	Philadelphia	25	40	Omaha	42	22	Long Beach
9	7	Oakland	26	28	San Diego	43	36	Colorado Springs
10	13	Baltimore	27	14	New Orleans	44	49	Indianapolis
11	20	Denver	28	17	Los Angeles	45	50	Virginia Beach
12	15	Milwaukee	29	48	Louisville	46	36	Memphis
13	18	Austin	30	41	Columbus	47	25	Las Vegas
14	10	Sacramento	31	27	Detroit	48	42	Tulsa
15	6	Washington	32	19	Phoenix	49	39	Oklahoma City
16	31	Cleveland	33	34	San Antonio	50	21	Mesa
17	2	Honolulu	34	23	Miami	*O = Overall* *M = Mode of Commute to Work*		

The top city of the mode of commute to work, San Francisco ranks the top in walk-score variable, 3rd city in drive alone, 4th city in public transportation, and 5th city in walk variable (see Appendix A). On the other hand, Virginia Beach is 48th in using public transportation. Also, this city is 46th in walking, 39th in walking score, 46th in drive alone and in bicycling 38th city.

In sum, the mode of commute to work has strong correlation with the overall ranking. The SustainLane overall ranking's variables are percentages of public transportation ridership, walk, bike, carpool and drive alone. However, in this analysis, motorcycle and walk score variables are added. Also, according to result of SPSS, the motorcycling and carpool variables are removed. This analysis supports that low ranking city' people use their own car and they do not use public transportation or bicycle on their commute. In addition, low ranking cities' walking score is lower than high ranking cities. Thus, low ranking cities' people cannot walk to their commute or other trip. That is one reason why low ranking cities' people drive alone percentage is bigger than high ranking cities.

4.3 Mean Travel Time to Work and Traffic Congestion Cost

Sprawl has an impact on travel demand and traffic congestion. These two performance criteria are not equivalent. All else being equal, more travel will translate into more congestion (Ewing R. H., 1994). Most people enjoy the personal mobility provided by the auto-highway system and the suburban lifestyles that it makes possible (Richardson & Gordon, 2000). There is extensive literature relating travel and traffic to urban form. Particularly, related to density, high densities generate fewer vehicle miles of travel (VMT) per capita than do low densities. Trips become shorter as densities rise, and a growing percentage of trips are made by walking or transit (Newman & Kenworthy, 1988). At the same time, high densities are associated with high levels of traffic congestion. The net effect of shorter trips and heightened congestion on travel times and travel costs is unclear *a priori*, but recent empirical evidence suggests that the former overwhelms the latter (Ewing, 1994). According to the 2007 Texas Transportation Institute (TTI) Annual Urban Mobility Report, public transportation reduces traffic delays and costs in America's urban areas. Also, public transportation helps alleviate congestion on the United States increasingly crowded network of roadways. Also, Gordon et al. stated that, a polycentric development pattern permits clustering of land uses to reduce trip lengths without producing the degree of congestion extant in a compact, centralized pattern (Gordon et al., 1989).

On the other hand, related to health, Barnett et al. (2007) explain that increasing traffic congestion and air pollution from autos are linked to a range of pulmonary, coronary, and neurological diseases such as asthma, cancer, heart disease, strokes, etc. Also he has examined the link between the sedentary lifestyles of our automobile culture and increasing rates of obesity and diabetes throughout the United States. On the economic side, Barnett et al. said that according to the annual study of urban mobility and traffic congestion published by the Texas Transportation Institute, the impacts on drivers in the fast-spreading multi-city regions described in this book are substantial indeed. Drivers in Los Angeles endure an average of 93 hours per year in congestion-related delays; Orlando drivers lose 51 hours, and Atlanta drivers lose 60 hours. Average annual delays in Dallas have increased more than fourfold, from 13 hours in 1982 to 61 hours in 2002. The Institute has concluded that congestion costs the American economy some $63 billion in lost productivity and wasted fuel in 2004 (Barnett et al., 2007). In addition, when the commuter drives on congested roadways to get to work, another cost is generated above and beyond the private cost due to the extra congestion caused by the commuter’s presence on the road. Such lower speed prolongs everyone’s trip, raising the time cost of travel for all commuters. Thus, on congested roads, the true social cost of commuting for an individual includes the costs imposed on other commuters through extra congestion. Although this extra congestion is slight, its impact is significant because many other commuters are affected. Because these congestion costs are borne by others, the commuter himself has no incentive to take them into account. This missing incentive constitutes a market failure, and means that commuting on congested roadways looks artificially cheap to individual commuters. Therefore, congested roads are overused (Brueckner, 2006). In short, congestion result from many people and freight moving at the same time; too many people, too many trips over too short a time period on a system that is too small; by events that are irregular, but frequent such as crashes, vehicle breakdowns, and improperly timed traffic signals. Sprawl causes long commutes and expensive traffic congestion cost. However, the compact city, consistent with high density, has a high level of congestion but at the same time the VMT is shorter. Finally, both urban forms cause traffic congestion. Also, according to the research of Ewing et al. (2002), 'percentage of urbanized area commuters who drive alone or in carpools' is one of methods for measuring sprawl. Also, the use of carpooling can decrease vehicle miles traveled, fuel consumption, and improve air quality. Thus, even though commuters in low ranking cities uses carpooling more than in higher ranking cities, they can reduce vehicle miles traveled, traffic congestion cost and air quality.

Nevertheless, according to the SustainLane's overall ranking and congestion's relationship result, they do not have a correlation because the p-value is higher than 0.05—p-value is 0.313(see Table 5). The explanation of this result is that the SustainLane used only one variable in their analysis which is the average time spent waiting in traffic. However, mean travel time to work, traffic congestion cost, speed and carpool are used in this thesis analysis. Also, my expected result is that these four variables have a correlation with the overall ranking. Thus, the hypotheses and analyses of these indicators are dependent on those four variables. The analysis of mean travel time to work uses mean travel time to work of workers 16 years and over who did not work at home from U.S. Census Bureau/American Fact Finder data. Traffic congestion cost and speed data is from the Texas Transportation Institute's 'The 2007 Urban Mobility Report.' The 2007 Urban Mobility Report based on the 437 urban areas. However, with this thesis' area, the data is about only 48 areas. And, there is a limitation with this approach. Because those area's physical boundaries are metropolitan area or urban area not a single city. The data of Long Beach and Mesa are not included. Furthermore, some cities were linked to their neighbor cities to make one metropolitan area such as Dallas-Fort Worth-Arlington and San Francisco-Oakland. This is the biggest of disadvantage of this analysis. However, in the SustainLane's Metro Congestion category, it also was analyzed using TTI's data (see Table 2). The different thing is that the SustainLane used TTI's data which was based on metro region public transit ridership miles and square miles per region. But in this thesis, TTI's traffic congestion cost and speed data are applied.

4.3.1 Mean Travel Time to Work

In relation to the previous studies, taking into consideration the distance from home to work, getting long mean travel time to work cities have developed a sprawl. Thus, the hypothesis would be that

H_4: High ranking cities have a correlation with mean travel time to work.

As a result of mean travel time to work and overall ranking relationship by SPSS, they have a statistically negative significance between overall ranking and the mean travel time to work. Because p-value is lower than 0.05. Also, the r-value is -0.369 and it means that low ranking cities' mean travel time to work is shorter than high ranking cities' (see Table 13).

Table 13 Correlations between Mean Travel Time to Work and SustainLane Overall ranking

		Mean Travel Time to Work
Overall Ranking	Pearson Correlation	-.369
	Sig. (2-tailed)	.008
	N	50

The shortest mean travel time to work city is Omaha (17.3 minutes) and the longest city is New York (39.8 minutes). Compared with the overall ranking, high ranking cities' mean travel time to work is longer than low ranking cities (see Table 13).

Following analysis result (see Table 13), the Mean Travel Time to Work has a moderate correlation with sustainability or compact city form. The graph of results shows that sustainable cities' mean travel times are longer than other cities (see Figure 11).

Table 14 New City Ranking by Mean Travel Time to Work

Ranking		City	Ranking		City	Ranking		City
O	M		O	M		O	M	
1	26	Portland, OR	18	8	Albuquerque, NM	35	25	Charlotte, NC
2	44	San Francisco, CA	19	34	Atlanta, GA	36	38	Houston, TX
3	29	Seattle, WA	20	9	Kansas City, MO	37	3	Fresno, CA
4	49	Chicago, IL	21	37	San Jose, CA	38	13	El Paso, TX
5	50	New York, NY	22	10	Tucson, AZ	39	27	Fort Worth, TX
6	45	Boston, MA	23	23	Jacksonville, FL	40	20	Nashville, TN
7	12	Minneapolis, MN	24	36	Dallas, TX	41	32	Arlington, TX
8	48	Philadelphia, PA	25	1	Omaha, NE	42	40	Long Beach, CA
9	41	Oakland, CA	26	21	San Diego, CA	43	4	Colorado Springs, CO
10	43	Baltimore, MD	27	18	New Orleans, LA	44	14	Indianapolis, IN
11	24	Denver, CO	28	46	Los Angeles, CA	45	15	Virginia Beach, VA
12	11	Milwaukee, WI	29	30	Louisville, KY	46	7	Memphis, TN
13	16	Austin, TX	30	6	Columbus, OH	47	31	Las Vegas, NV
14	17	Sacramento, CA	31	39	Detroit, MI	48	2	Tulsa, OL
15	47	Washington, DC	32	35	Phoenix, AZ	49	5	Oklahoma City, OK
16	28	Cleveland, OH	33	22	San Antonio, TX	50	33	Mesa, AZ
17	19	Honolulu, HI	34	42	Miami, FL	*O = Overall / M = Mean Time to Work*		

The United States' mean travel time to work from home is 25.3 minutes. In New York, the commute takes almost 40 (39.8) minutes on average; the second longest city is Chicago at 35 minutes. The city with the shortest average commute time is Omaha at 17.3 minutes. The gap between Omaha and New York is 22.5 minutes. Moreover, in Figure 9, the result is not even but seems that the low ranked cities' mean travel time to work is shorter than high ranked cities'. Plus, among the 50 cities, 31 cities' mean travel time to work is longer that the United States average (see Appendix A).

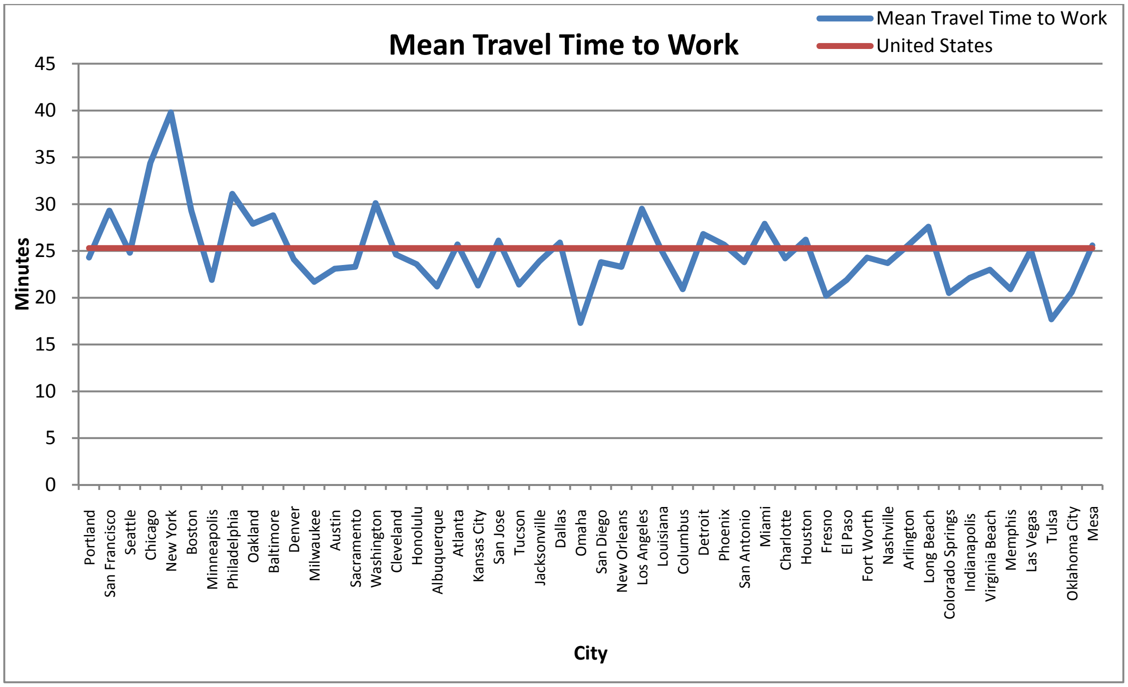

Figure 11 Mean Travel Time to Work

4.3.2 Traffic Congestion Cost

Similar to the previously cited studies, regarding traffic congestion cost, long commute distances increase travel time to work. The data of this analysis does not include Long Beach and Mesa's traffic congestion cost. Also, it is collected by metropolitan area boundary rather than city limit boundary, so the data ccategories are not strictly comparable. However, it is a valid indicator because traffic congestion is a metropolitan phenomenon that is not limited by city boundaries. The traffic congestion cost is the value of travel time delay and fuel consumption. The value of travel time delay estimated at $ 14.60 per hour of person travel and $77.10 per hour of truck time. The hypothesis of traffic congestion cost is

H_5: High ranking cities have a correlation with more traffic congestion cost.

The r-value is -0.341 which explains that traffic congestion costs have a moderate negative correlation with overall ranking (see Table 14). According to SPSS analysis result, there is a statistically negative significant between overall ranking and traffic congestion cost. The p-value is 0.018, it is lower than 0.05 (see Table 15). This result meaning is that high ranking cities have higher traffic congestion costs than low ranking cities.

Table 15 Correlations between Traffic Congestion Cost and SustainLane Overall Ranking

		Traffic Congestion Cost
Overall Ranking	Pearson Correlation	-.341
	Sig. (2-tailed)	.018
	N	48

Compared with overall ranking, in the new ranking of traffic congestion cost, the most expensive traffic congestion cost city is Los Angeles ($9,325 million) and the next expensive city is New York ($7,383 million) (see Table 16 and Appendix A). The cheapest traffic congestion cost city is Fresno ($127 million). The next cheapest city is Colorado Springs ($131 million). The gap of the most expensive city and the cheapest city is large (see Figure 12). In the traffic congestion costs ranking, the most moved down cities are New York and Chicago. In the overall ranking, New York was 5th city and Chicago was 4th city. However, in the traffic congestion cost ranking, New York and

Chicago ranked 45th and 44th respectively. Also, the city that raised most in the rankings is Tulsa; this city was 48th in the overall ranking but Tulsa is 3rd city in traffic congestion cost ranking.

Table 16 New City Ranking by Traffic Congestion Cost

Ranking		City	Ranking		City	Ranking		City
O	C		O	C		O	C	
1	25	Portland, OR	18	8	Albuquerque, NM	35	19	Charlotte, NC
2	39	San Francisco, CA	19	41	Atlanta, GA	36	37	Houston, TX
3	31	Seattle, WA	20	11	Kansas City, MO	37	1	Fresno, CA
4	44	Chicago, IL	21	27	San Jose, CA	38	5	El Paso, TX
5	45	New York, NY	22	14	Tucson, AZ	39	43	Fort Worth, TX
6	34	Boston, MA	23	15	Jacksonville, FL	40	17	Nashville, TN
7	28	Minneapolis, MN	24	43	Dallas, TX	41	43	Arlington, TX
8	35	Philadelphia, PA	25	4	Omaha, NE	42		Long Beach, CA
9	39	Oakland, CA	26	33	San Diego, CA	43	2	Colorado Springs, CO
10	29	Baltimore, MD	27	9	New Orleans, LA	44	22	Indianapolis, IN
11	30	Denver, CO	28	46	Los Angeles, CA	45	21	Virginia Beach, VA
12	12	Milwaukee, WI	29	16	Louisville, KY	46	13	Memphis, TN
13	20	Austin, TX	30	18	Columbus, OH	47	24	Las Vegas, NV
14	26	Sacramento, CA	31	36	Detroit, MI	48	3	Tulsa, OL
15	38	Washington, DC	32	32	Phoenix, AZ	49	7	Oklahoma City, OK
16	10	Cleveland, OH	33	23	San Antonio, TX	50		Mesa, AZ
17	6	Honolulu, HI	34	42	Miami, FL	*O = Overall / C = Traffic Congestion Cost*		

Cost is also an important consideration of congestion impacts. Americans living in transit-intensive metropolitan areas save $10.2 billion annually in congestion costs. Every $10 million invested in public transportation saves more than $15 million, for both highway and transit users (Americal Public Transportation Association, 2008).

Consequently, with a cheap congestion cost city is more sustainable. Figure 10 shows traffic congestion cost from ‘The 2007 Urban Mobility Report.’ The average traffic congestion cost of the 50 cities in the SustainLane rankings is $1,311 million per region. The traffic congestion cost of the most congested city, Los Angeles, is seven times more expensive than the average city’s cost. On the other hand, the traffic congestion cost of the top city, Fresno, is ten times cheaper than the average cost of the 50 cities (see Appendix A).

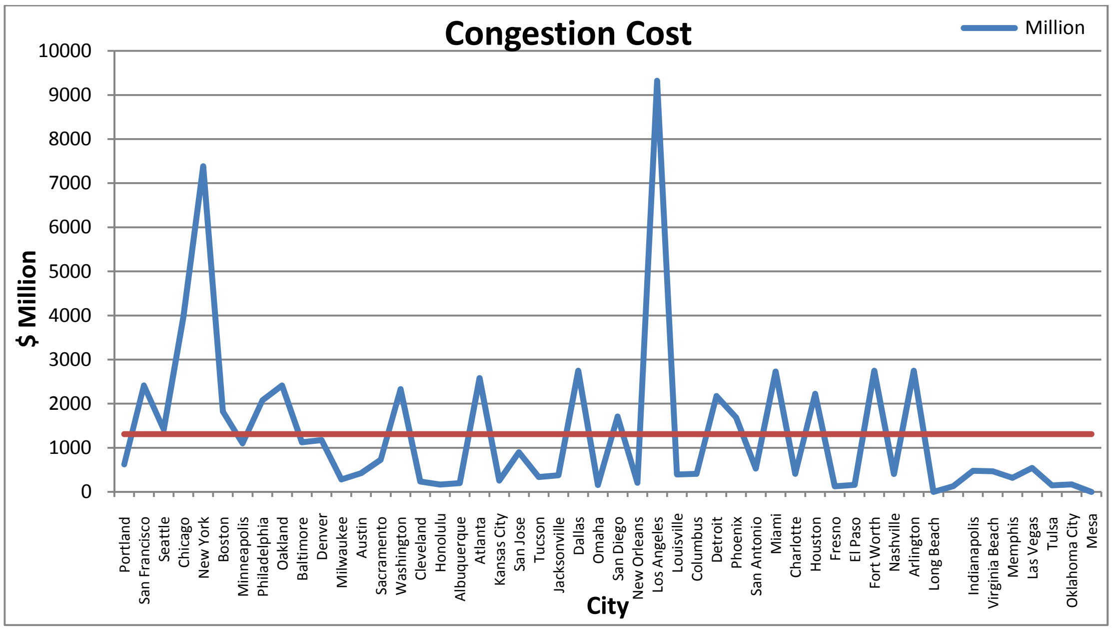

Figure 12 Traffic Congestion Cost

4.3.3 Speed

Low speed makes travel trips longer, raising the time cost of travel for all commuters. Thus, sprawl has a lower speed than compact city. Thus, the hypothesis of speed is

H_6: High ranking cities have a correlation with high speed.

Along with SPSS analysis of speed and overall ranking result, there is a statistically negative significance between overall ranking and speed. The speed of freeway and arterial streets' p-values are 0.007 and 0.017, both of which are lower than 0.05 and thus statistically significant. The r-values are -0.385 and -0.343, respectively, which explains that the speeds of freeway and arterial streets have a moderate negative correlation with overall ranking (see Table 17).

Table 17 Correlations between Speed and Overall Ranking

	Speed	Freeway	Arterial street
Overall Ranking	Pearson Correlation	-.385	-.343
	Sig. (2-tailed)	.007	.017
	N	48	48
Freeway	Pearson Correlation		.696
	Sig. (2-tailed)		.000
	N		48

This result meaning is that low ranking cities' car speed is faster than high ranking cities' speed on the freeway and arterial streets both. Also, the relationship between speeds of freeway and arterial streets has a statistically significant correlation between themselves. The p-value is 0.00 and r-value is 0.696. The result shows that there is a strong correlation between freeway and arterial streets speeds (see Table 17). A city with fast speeds on freeway also has fast speeds on arterial streets.

Table 18 New Speed Ranking

City	O	Speed Ranking		City	O	Speed Ranking	
		Arterial Street	Freeway			Arterial Street	Freeway
Portland	1	22	30	Omaha	25	12	8
San Francisco	2	44	45	San Diego	26	41	39
Seattle	3	25	34	New Orleans	27	11	6
Chicago	4	48	47	Los Angeles	28	43	48
New York	5	40	40	Louisville	29	21	22
Boston	6	17	24	Columbus	30	15	16
Minneapolis	7	13	27	Detroit	31	37	23
Philadelphia	8	28	25	Phoenix	32	24	38
Oakland	9	45	45	San Antonio	33	26	21
Baltimore	10	27	28	Miami	34	47	37
Denver	11	36	31	Charlotte	35	30	18
Milwaukee	12	1	20	Houston	36	31	44
Austin	13	35	26	Fresno	37	9	4
Sacramento	14	39	32	El Paso	38	8	19
Washington	15	46	35	Fort Worth	39	19	42
Cleveland	16	3	5	Nashville	40	16	9
Honolulu	17	29	15	Arlington	41	20	43
Albuquerque	18	10	17	Long Beach	42		.
Atlanta	19	34	36	Colorado Springs	43	7	10
Kansas City	20	2	3	Indianapolis	44	32	12
San Jose	21	42	33	Virginia Beach	45	14	13
Tucson	22	23	14	Memphis	46	5	11
Jacksonville	23	38	7	Las Vegas	47	33	29
Dallas	24	18	41	Tulsa	48	6	1
Omaha	25	12	8	Oklahoma City	49	4	2
San Diego	26	41	39	Mesa	50		.

O = Overall Ranking

Compared with the overall ranking (see Table 18), in the new ranking of arterial streets, the fastest speed city is Tulsa and the lowest speed city is Los Angeles on the freeway. Moreover, on the arterial streets, the fastest speed city is Milwaukee and the lowest speed city is Chicago. In the freeway speed ranking, the most moved up cities are

Tulsa and Oklahoma City. These cities ranked 48th and 49th in the overall ranking. However, in the freeway speed ranking, Tulsa and Oklahoma ranked by 1st and 2nd. Conversely, the most moved down city is San Francisco. This city was 2nd in the overall ranking but in this freeway ranking San Francisco is 45th city.

In the arterial streets ranking, the most raised city is Oklahoma City again. In the arterial streets speed ranking, Oklahoma City is 4th fast speed city. However, the most fallen city is Chicago in the arterial streets ranking. Chicago was 4th city in the overall ranking but 48th city in the arterial streets ranking. This indicator's result explains that low ranking cities have faster speeds on both freeways and arterial streets than high ranking cities.

4.3.4 Carpool

Consistent with the previous studies and the mode of commute to work analysis findings, a large percentage of cities whose commuters use a carpool have a short mean travel time to work and cheap traffic congestion cost. Thus, the hypothesis of carpool and mean travel time to work & traffic congestion cost would be that

H_7: Carpool has a correlation with mean travel time to work and traffic congestion cost.

According to SPSS analysis of carpool and mean travel time to work & traffic congestion cost, there is a no statistically significant between and mean travel time to work & traffic congestion cost (see Table 19).

Table 19 Correlations between Carpool and Mean Travel Time to Work & Traffic Congestion Cost

		Mean Travel Time to Work	Traffic Congestion Cost
Carpool	Pearson Correlation	.272	.277
	Sig. (2-tailed)	.056	.057
	N	50	48

The mean travel time to work and traffic congestion cost' p-values are 0.56 and 0.57, both are much higher than 0.05. Thus, it explains that the low ranking cities do not have a correlation with short mean travel time to work and cheap traffic congestion cost. Therefore, this thesis does not support the theory that carpool can reduce the mean travel time to work and traffic congestion cost.

4.3.5 Summary of Mean Travel Time to Work and Traffic Congestion Cost

So far, using four variables to assess: 1) mean travel time to work, 2) traffic congestion cost, 3) speed, and 4) carpool. All of the four variables results by SPSS, analysis suggest that all four variables have a statistically significant negative correlation with the overall ranking. The levels of four variables' significance are generally moderate. This result means that 1) high ranking cities have longer mean travel time to work than low ranking cities, 2) high ranking cities have more expensive traffic congestion cost than low ranking cities, 3) high ranking cities' car speed is lower than low ranking cities on both freeways and arterial streets, 4) high ranking cities people do not carpool more than low ranking cities (see Table 20).

Table 20 Correlation between Four Variables

		Mean travel time to work	Traffic Congestion Cost	Speed of Freeway	Speed of Arterial Street	Carpool
Overall Ranking	Pearson Correlation	-.369	-.341	-.385	-.343	-.421
	Sig. (2-tailed)	.008	.018	.007	.017	.002
	N	50	48	48	48	50
Mean Travel Time to Work	Pearson Correlation		.840	.753	.700	.272
	Sig. (2-tailed)		.000	.000	.000	.056
	N		48	48	48	50
Traffic Congestion Cost	Pearson Correlation			.899	.698	.277
	Sig. (2-tailed)			.000	.000	.057
	N			48	48	48
Speed of Freeway	Pearson Correlation				.696	.156
	Sig. (2-tailed)				.000	.289
	N				48	48
Speed of Arterial	Pearson Correlation					.195
	Sig. (2-tailed)					.184
	N					48

The correlations among these four variables: (except related with carpool) suggest that mean travel time to work, traffic congestion cost, and speed are statistically significant. All of those p-values are 0.00 and r-values are over 0.6 (see Table 20). These three variables have a really strong correlation. The strongest relationships are traffic congestion cost and freeway speed. This result explains that fast speed on freeway city has cheap traffic congestion cost. Also, longer mean travel time to work makes more expensive traffic congestion. As well, cities with faster speeds on freeways and arterial streets have a shorter mean travel time to work. This new mean travel time to work and congestion cost ranking (see Table 21) and the overall ranking from the SustainLane have a statistically negative significant relationship. The p-value is 0.022 and r-value is -0.324 (see Table 22).

Table 21 Mean Travel Time to Work & Congestion Cost New Ranking

City	Ranking O	Ranking N	City	Ranking O	Ranking N	City	Ranking O	Ranking N
Portland	1	25	Albuquerque	18	8	Charlotte	35	22
San Francisco	2	45	Atlanta	19	40	Houston	36	41
Seattle	3	28	Kansas City	20	5	Fresno	37	2
Chicago	4	48	San Jose	21	39	El Paso	38	11
New York	5	46	Tucson	22	14	Fort Worth	39	33
Boston	6	29	Jacksonville	23	20	Nashville	40	15
Minneapolis	7	18	Dallas	24	37	Arlington	41	37
Philadelphia	8	36	Omaha	25	5	Long Beach	42	
Oakland	9	44	San Diego	26	34	Colorado Springs	43	4
Baltimore	10	31	New Orleans	27	9	Indianapolis	44	18
Denver	11	30	Los Angeles	28	47	Virginia Beach	45	16
Milwaukee	12	9	Louisville	29	21	Memphis	46	7
Austin	13	24	Columbus	30	13	Las Vegas	47	27
Sacramento	14	26	Detroit	31	35	Tulsa	48	1
Washington	15	42	Phoenix	32	32	Oklahoma City	49	3
Cleveland	16	12	San Antonio	33	22	Mesa	50	
Honolulu	17	17	Miami	34	43	*O = Overall / N = New*		

This result explains that high ranking cities have long mean travel time to work and expensive congestion cost. Also on the freeway and Arterial streets, their car speed is lower than low ranking cities.

Table 22 Correlation between New and Overall Ranking

		Mean Travel Time to Work & Congestion Cost New Ranking
Overall Ranking	Pearson Correlation	-.324
	Sig. (2-tailed)	.022
	N	50

Table 21 and Table 22 show that high ranking cities, in the overall ranking from SustainLane, ranked bottom in the new mean travel time to work and congestion cost ranking. All these cities, in the top ten in the overall ranking, downgraded and in the bottom ten in the overall ranking, upgraded in the new ranking. In the new ranking, the most moved down city is Chicago. It was 4th city in the overall ranking but 48th city in the new. Also, Chicago ranked 49th city in the mean travel time to work result, 44th in the congestion cost ranking, 48th and 47th in the arterial streets and freeway speed ranking. On the other hand, the most moved up city is Tulsa. It was 48th city in the overall ranking but 1st city in the new ranking. In addition, Tulsa is 2nd city in mean travel time to work ranking, 3rd city in the congestion cost ranking, and 6th city in the arterial streets speed. Furthermore, Tulsa is the top city in the freeway speed ranking.

The high ranking cities have long commute to work and expensive congestion cost. Many researches and studies insist that short VMT can make short mean travel time to work and cheap traffic congestion cost. However, according to analysis results, the conclusion demonstrates opposite results. The short VMT makes long mean travel time to work and expensive traffic congestion cost.

4.4 Planning & Land Use

Urban and suburban centers may be large or small and may have single or mixed uses. Among these, sustainable urban form emphasizes a human scale, walkable community with moderate to high residential density and a mixed use core. Mixed land use is defined as the relative proximity of different land uses within a given area. A mixed-use neighborhood would include not just homes but also stores, offices, parks, and perhaps other land uses (Handy et al., 2002). Mixing complementary land uses reduces trip lengths and encourages alternatives to the automobile. Indeed, since dense urban environments tend to be mixed-use environments, the positive impacts attributed to density in the literature may result from mixed uses. Cities with the highest rates of walking and bicycling are those with a balance of jobs and residents in their central cities; high employment densities alone do not foster alternatives to the automobile (Newman & Kenworthy, 1989).

Thus, the high ranked cities have a more mixed land use, high street connectivity, and strong centeredness than low ranked cities. To test that each city's mixed land use, centeredness, and street connectivity are analyzed. The data is from 'Smart Growth America'. SGA has already measured sprawl using these three variables and density. In this analysis, mixed land use, centeredness and street connectivity are used because density analysis was already done in section 4.1 in this thesis. SGA's data' began with 139 metro areas, but many metro areas had to be dropped because of a lack of complete data. As a result, the final sample of the U.S. metropolitan areas consists of 84 metropolitan areas. This includes every metro over 500,000 population for which a complete dataset was available. The basic unit of analysis is a piece of geography created by the Census Bureau and known as a metropolitan statistical area or a primary metropolitan statistical area, or PMSA. PMSAs are generally larger than political jurisdictions such as cities, but smaller than the entire metropolitan region; some regions may include several PMSAs which are then combined to form a Combined Metropolitan Statistical Area (CMSA). Also fifteen variables were combined into three sprawl factors using a technique known as principal component analysis. Six variables to the land use mix factor, six variables to degree of centering factor, and three variables to the street accessibility factor (Ewing, Pendall, & Chen, 2002).

This thesis area 44 cities is of the SGA's 83 metropolitan areas in their indicator's. The limitation of using the SGA metro data in is physical boundary, the metropolitan area rather than a single city. Furthermore, Charlotte, Nashville, Louisville, and Mesa are not included this data. Furthermore, some cities were linked to their neighbor cities to make one metropolitan area such as Fort Worth-Arlington, Los Angeles-Long beach, and Virginia Beach-Newport News. Thus, the linked neighbor cities get same score with their neighbor cities such as Fort Worth and Arlington have a same score. This is a weakness in this indicator's analysis. This is a limitation to this indicator's analysis. However, in the SustainLane planning and land use category, they used SGA's data also (see Table 3). The different thing is that the SustainLane used SGA's data and their own primary research. Also, they added the percentage of park area. But in this analysis, mixed land use, centeredness and street connectivity are only used from SGA's data. Cause, only three variables are directly related with urban form.

4.4.1 Mixed Land Use

Regarding the mixed land use factor, SGA's data is based on 'land use impacts on travel' from Ewing & Cervero's research , titled 'Travel and the Built Environment', (2001). According to their research, three types of mixed land use represent a relative balance between jobs and population within subareas of the region, the diversity of land uses within subareas of a region, and the accessibility of residential uses to nonresidential uses at different locations within a region. All these types were estimated for metropolitan areas in the samples and became part of the mixed land use indicator. Three mixed use variables are derived from the national micro-data samples of the American Housing Survey: percentage of residents with businesses or institutions within 1/2 block of their homes; percentage of residents with satisfactory neighborhood shopping within 1 mile; percentage of residents with a public elementary school within 1 mile (see Table 23).

Table 23 Variables and Sources of Mixed Land Use

Variable	Source
Percentage of residents with businesses or institutions within 1/2 block of their homes	American Housing Survey
Percentage of residents with satisfactory neighborhood shopping within 1 mile	
Percentage of residents with a public elementary school within 1 mile	
Balance of jobs to residents	Census Transportation Planning Package
Balance of population serving jobs to residents-Population serving jobs include retail, personal services, entertainment, health, education, and professional services	
Mix of population serving jobs	

Also three additional mixed land use variables are derived from the Census Transportation Planning Package (CTPP) for 1990. The CTPP is the only census product that summarizes data by place of work as well as by place of residence; it alone measures the degree of balance between employment and population for subareas of metros as well as the degree of employment mixing for subareas; Balance of jobs to residents; Balance of population serving jobs to residents; population serving jobs include retail, personal services, entertainment, health, education, and professional services and mix of population serving jobs (Ewing, Pendall, & Chen, 2002). Thus, the hypothesis of mixed land use would be that

H_8: High ranking cities have a correlation with strong mixed land use.

As a result of mixed land use and overall ranking relationship by SPSS, there is no statistically significant between overall ranking and mixed land use. Because the p-value (0.177) is higher than 0.05 and the r-value is so low (0.202) (see Table 24).

Table 24 Correlations between Mixed Land Use and SustainLane Overall Ranking

		Mixed Land Use
Overall Ranking	Pearson Correlation	.202
	Sig. (2-tailed)	.177
	N	46

This result means that high ranking cities, namely sustainable cities do not have a correlation with mixed land use. It is totally opposite result with previous research results. Following many researches and articles, stronger mixed land use is most representative characteristic of compact city form. However, following this analysis, the result said that mixed land use and sustainability has no relationship.

4.4.2 Centeredness

Regarding centeredness, metropolitan centers are concentrations of activity that provide agglomeration economies, support alternative modes and multipurpose trip making, create a sense of place in the urban landscape, and otherwise differentiate compact metros from sprawling ones (Ewing R. , 1997). Centeredness can exist with respect to population or employment, and with respect to a single dominant center or multiple sub-centers. The technical literature associates compactness with centers of all types, and sprawl with the absence of centers of any type. All six variables include centeredness (see Table 25).

Table 25 Variable and Source of Centeredness

Variable	Source
Variation of population density by census tract	US Census
Rate of decline in density from center (density gradient)	
Percentage of population living within 3 miles of the central CBD	Edward Glaeser,
Percent of the population living more than 10 miles from the CBD	
Percentage of the population relating to centers within the same metropolitan statistical area	Claritas
Ratio of population density to the highest density center in the metro area	

Two came from the U.S. Censuses of 1990 and 2000—variation of population density by census tract and rate of decline in density from center. Also, the degree of centralization of employment within the metropolitan area form the literature of ‘Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept’ (Galster et al., 2001) with two variables percentage of metropolitan population less than 3 miles from the CBD and percentage of metropolitan population more than 10 miles from the CBD. For the 100 largest U.S. metropolitan areas, Galster et al. (2001) calculated the share of overall metropolitan area employment within a three-mile ring of the Central Business District, the share of metropolitan area employment within a 10-mile ring of this spot, and the share beyond the 10-mile ring. Other variables came from Claritas databases which identified population centers and their spheres of influence. Claritas divided the US into 900,000 cells of 1/30 degree longitude and latitude, or approximately 4 square miles each. Densities were computed for all them, and local density maxima defined as cells whose densities are greater or equal to those of all the grid cells surrounding them or in the second ring around them (approximately a 5-mile radius). A local density maximum was treated as a population center for another cell if a route could be constructed from the latter to the former, traveling cell by cell in any of eight possible directions along the grid, in which the density of each successive cell always increased or remained equal, and that route was shorter than that to all other competing local density maxima. Defined this way, the most dense population centers are at the hearts of big cities, while the least dense are very rural. Each block group within a metropolitan area was related to; a population center in the same metro; a population center in a different metro; a population center outside all metropolitan areas; or no population center at all; percentage of the metropolitan population relating to centers or sub-centers within the same MSA or PMSA; ratio of the weighted density of population centers within the same MSA or PMSA to the highest density center to which a metro relates (Ewing, Pendall, & Chen, 2002). Therefore, the centeredness hypothesis would be that

H_9: High ranking cities have a correlation with strong centeredness.

As a result of centeredness and overall ranking relationship by SPSS is that there is no statistically significant between overall ranking and mixed land use, because the p-value (0.129) is higher than 0.05 and the r-value is so low (0.237) (see Table 26).

Table 26 Correlations between Centeredness and SustainLane Overall Ranking

		Centeredness
Overall Ranking	Pearson Correlation	.227
	Sig. (2-tailed)	.129
	N	46

The result of centeredness and overall ranking's relationship is same as the result of mixed land use and overall ranking's relationship. Centeredness also does not have a correlation with overall ranking. It means that centeredness and sustainability do not have a relationship.

4.4.3 Street Connectivity

Street networks can be dense or sparse, interconnected or disconnected, straight or curved. Blocks carved out by streets can be short and small, or long and large. Sparse, discontinuous, curvilinear networks creating long, large blocks have come to be associated with the concept of sprawl, while their antithesis is associated with compact development patterns. Connectivity is defined as the directness and availability of alternative routes from one point to another within a street network (Handy et al, 2002). Grid street networks, compared with other patterns, have better connectivity and provide shorter distances between destinations. Local street networks servicing a residential area should have good interconnectivity with each other as well as appropriate connections with arterial roads (Soltani & Bosman, 2005). In addition, better connectivity leads to more walking and biking, fewer vehicle miles traveled, better air quality, and a greater sense of community among residents (Benfield, Raimi, & Chen, 1999).

Table 27 Variables and Sources of Street Connectivity

Variable	Source
Average block length in urbanized portion of the metro area	Census Tiger Files
Average block size in square miles	
Percentage of small blocks	

For the analysis, SGA used the data from U.S. Census TIGER files to determine block lengths. To a degree, block size not only captures the length of block faces but the extent to which streets are interconnected, as suburban superblocks with branching streets ending in cul-de-sacs may appear fairly dense and short-blocked, but are still large in total area. Block length is described as ‘approximate’ because not all street segments in the TIGER files end at intersections. According to the Census Tiger Files, three variables are derived (see Table 27); approximate average block length in the urbanized portion of the metro; average block size in square miles (excluding blocks > 1 square mile); percentage of small blocks (< 0.01 square mile) (Ewing et al., 2002). The hypothesis of street connectivity is

H_{10}: *High ranking cities have a correlation with street connectivity.*

As a result of street connectivity and overall ranking relationship by SPSS, there is a statistically significant between overall ranking and street connectivity; because the p-value is lower than 0.011 and the r-value is 0.373. Thus, the hypothesis which high ranking cities do not have a correlation with street connectivity is rejected and the overall ranking and street connectivity has a moderate correlation (see Table 28).

Table 28 Correlations between Street Connectivity and Overall Ranking

		Street Connectivity
Overall Ranking	Pearson Correlation	.373
	Sig. (2-tailed)	.011
	N	46

This result means that high ranking cities' street connectivity is strong than low ranking cities'. In addition to, this result explains that high ranking cities' street networks are more dense, interconnected, and straight than low ranking cities'.

Table 29 New Ranking by Street Connectivity

Ranking		City	Ranking		City	Ranking		City
O	S.C.		O	S.C.		O	S.C.	
1	7	Portland	18	13	Albuquerque	35		Charlotte
2	2	San Francisco	19	46	Atlanta	36	33	Houston
3	14	Seattle	20	38	Kansas City	37	43	Fresno
4	5	Chicago	21	9	San Jose	38	25	El Paso
5	1	New York	22	39	Tucson	39	28	Fort Worth
6	12	Boston	23	22	Jacksonville	40		Nashville
7	40	Minneapolis	24	37	Dallas	41	28	Arlington
8	17	Philadelphia	25	23	Omaha	42	10	Long Beach
9	6	Oakland	26	20	San Diego	43	31	Colorado Springs
10	21	Baltimore	27	3	New Orleans	44	41	Indianapolis
11	8	Denver	28	10	Los Angeles	45	16	Virginia Beach
12	35	Milwaukee	29		Louisville	46	42	Memphis
13	34	Austin	30	30	Columbus	47	18	Las Vegas
14	26	Sacramento	31	36	Detroit	48	32	Tulsa
15	27	Washington	32	19	Phoenix	49	44	Oklahoma City
16	45	Cleveland	33	24	San Antonio	50		Mesa
17	15	Honolulu	34	4	Miami	*O = Overall* *S.C. = Street Connectivity*		

Based on the street connectivity score, new ranking of street connectivity is made and compared with SustainLane overall ranking. In the new ranking, the top city is New York (92.9 score). The next city is San Francisco (83.8) and New Orleans (83.1) is 3rd city in the street connectivity ranking. On the other hand, the last city is Atlanta (34.2). Cleveland (40.0) is 45th city and Oklahoma City (41.4) is 44th city in the street connectivity. The most moved up city is Long Beach (73.9) and the most moved down city is Minneapolis (52.6) (see Table 29 and Appendix A). Long Beach was 42nd city in the SustainLane overall ranking but in the street connectivity ranking this city is 10th.

Oppositely, Minneapolis was 7th city in the SustainLane overall ranking but 40th city in the street connectivity.

4.4.4 Summary of Planning & Land Use

Based on mixed land use, centeredness and street connectivity, this research found several results about the relationship between sustainability and urban form. First, relationship with overall ranking, mixed land use and centeredness do not have a correlation. Only street connectivity has a correlation with overall ranking, even though the correlation strength is not strong. Second, the relationship among mixed land use, centeredness and street connectivity, they have no correlation with each by each.

Table 30 tion with Planning and Land Use and Overall Ranking

		Mixed Land Use	Centeredness	Street Connectivity
Overall Ranking	Pearson Correlation	.202	.227	.373
	Sig. (2-tailed)	.177	.129	.011
	N	46	46	46
Mixed Land Use	Pearson Correlation		.143	.174
	Sig. (2-tailed)		.343	.247
	N		46	46
Centered-ness	Pearson Correlation			.097
	Sig. (2-tailed)			.521
	N			46

It means that mixed land use, centeredness and street connectivity do not have an effect on each other (see Table 30). According to the analyses result of mixed land use, centeredness and street connectivity, planning and land use ranking is decided (see Table 31). This ranking is based on the average score by each city.

Table 31 Planning and Land Use New Ranking

City	Ranking		City	Ranking		City	Ranking	
	Overall	P/L		Overall	P/L		Overall	P/L
Portland	1	6	Albuquerque	18	7	Charlotte	35	
San Francisco	2	2	Atlanta	19	46	Houston	36	30
Seattle	3	29	Kansas City	20	40	Fresno	37	18
Chicago	4	12	San Jose	21	24	El Paso	38	18
New York	5	1	Tucson	22	22	Fort Worth	39	42
Boston	6	3	Jacksonville	23	33	Nashville	40	
Minneapolis	7	34	Dallas	24	45	Arlington	41	42
Philadelphia	8	10	Omaha	25	4	Long Beach	42	15
Oakland	9	25	San Diego	26	27	Colorado Springs	43	8
Baltimore	10	10	New Orleans	27	9	Indianapolis	44	37
Denver	11	5	Los Angeles	28	15	Virginia Beach	45	34
Milwaukee	12	14	Louisville	29		Memphis	46	36
Austin	13	20	Columbus	30	38	Las Vegas	47	30
Sacramento	14	26	Detroit	31	44	Tulsa	48	27
Washington	15	38	Phoenix	32	21	Oklahoma	49	40
Cleveland	16	32	San Antonio	33	23	Mesa	50	
Honolulu	17	12	Miami	34	15	*P/L = Planning and Land Use*		

According to the overall new ranking of planning and land use, 21 cities ranking become lower and others got higher. The top city in planning and land use ranking is New York and last ranked city is Atlanta. New York is ranked 1st city in street connectivity and 2nd city centeredness and mixed land use. Otherwise, Atlanta is ranked 46th city in street connectivity, 45th city in mixed land use, and 37th city in centeredness. The city having the biggest gap is Colorado Springs. The original overall ranking of this city was 43rd, but in planning and land use this city is ranked 8th. Colorado Springs is upgraded 35th ranking; 9th city in mixed land use, 3rd city in centeredness and 31st city in street connectivity. Even though Colorado Springs was un-sustainable city in the overall ranking but this city has a compact city form, particularly strong mixed land use and centeredness. On the other hand, Atlanta was 19th city in the overall ranking but in the planning & land use ranking it ranked 46th. Atlanta is downgraded 27th ranking. Hence, Atlanta has the most sprawled urban form, according to this analysis.

Among 50 cities, San Francisco is noticeable because it is ranked 2nd in both rankings—SustainLane overall ranking and new planning & land use ranking; 2nd city in street connectivity, 5th city in centeredness and 17th city in mixed land use. San Francisco has a strong street connectivity and centeredness but there's mixed land use is not strong. However, San Francisco is truly the most sustainable city because this city was one of the high ranked cities in the overall ranking and one of strong cities in the planning and land use ranking. Therefore San Francisco has a compact city form. Oppositely, Oklahoma City is an un-sustainable and having sprawl urban form. The reason of that Oklahoma City ranked 49th in the SustainLane overall ranking and 40th in new planning and land use ranking respectively.

Table 32 Correlation between SustainLane Overall Ranking and Planning & Land Use Ranking

		Planning and Land Use
Overall Ranking	Pearson Correlation	.421
	Sig. (2-tailed)	.004
	N	46

The result from SPSS, conclusion is that there is a statistically significant relationship between the SustainLane overall ranking and planning & land use new ranking (see Table 32). The p-value is lower than 0.05 and r-value is 0.421. Therefore, overall ranking and planning & land use ranking has a moderate correlation. This result's meaning is that high ranking cities in SustainLane overall ranking is also high ranked in new planning & land use. In the other words, sustainable cities' planning and land use ranking is higher than un-sustainable cities. According to this result, high ranking cities have a strong mixed land use, centeredness and street connectivity.

Table 33 Correlations with Planning & Land Use and Each Indicator

		Mixed Land Use	Centeredness	Street Connectivity
Planning & Land Use	Pearson Correlation	.638	.622	.659
	Sig. (2-tailed)	.000	.000	.000
	N	46	46	46

However, only street connectivity has a correlation with overall ranking. In addition to, with the planning and land use result, all of these—mixed land use, centeredness and street connectivity—have a correlation each by each (see Table 33). All of those p-values are lower than 0.05 and r-values over 0.5. Therefore, mixed land use, centeredness and street connectivity have a statistically significant relationship with planning and land use. Table 29 explains that high ranked cities in planning and land use result have a strong mixed land use, centeredness and street connectivity when these three variables were combined.

4.5 Summary of Indicators analysis

To this point, the sustainable city ranking from SustainLane and each indicator were analyzed and compared. In this analysis and comparison, whole four indicators were used—density, mode of commute to work, mean travel time & congestion cost, and planning & land use. Among these, some indicators included sub variables. The mode of commute to work included seven variables—walking, bicycling, motorcycling, walk score, carpool, public transportation, and drive alone. The mean travel time & traffic congestion cost includes four variables—mean travel time, congestion cost and speed on freeway & arterial streets. The planning and land use includes three variables—mixed land use, centeredness and street connectivity. All fifteen variables were analyzed and compared with SustainLane overall ranking (see Figure 13). Each indicator and variables were scored, ranked and compared with the overall ranking from SustainLane.

Essentially, in this thesis, the hypothesis is based on the theory that sustainable city has a compact city form. According to the SustainLane 2008 US sustainable city ranking, high ranked cities were considered sustainable cities. Also, low ranked cities were regarded as un-sustainable cities. Thus, the indicators' entire hypotheses are based on compact city's characteristics. Used SPSS's correlation analysis tool, first figured out the relationship between overall ranking and the indicators and variables. The finding of the analysis of the relationship between each indicator and urban form yields very mixed results (see Table 32).

With the overall ranking and the indicators and variables' correlation is that all four indicators have a statistically significant relationship with overall ranking. Related with this thesis' hypothesis, expected results were that high ranked cities in the SustainLane overall ranking have a 1) high density, 2) sustainable mode of commute to work, 3) short mean travel time to work, cheap congestion cost and high speed on freeway and arterial streets both, 4) strong mixed land use, centeredness, and street connectivity than low ranked cities in the SustainLane overall ranking.

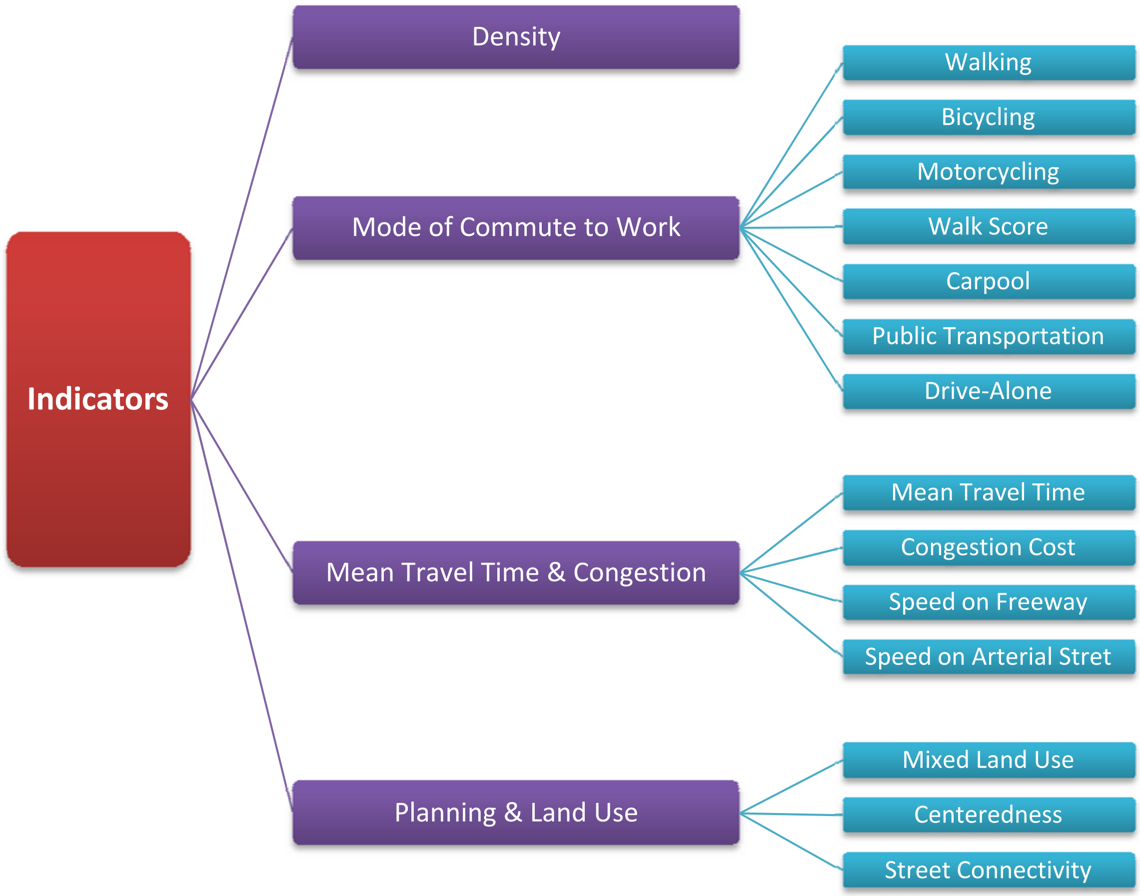

Figure 13 Compact City Indicators

According to the analyses results, the strongest correlation with overall ranking is the mode of the commute to work; r-value is 0.719. Next indicator is density as the r-value is 0.598 and then the planning and land use indicator have a correlation with overall ranking as the r-value is 0.417. On the other hands, the mean travel time to work and traffic congestion cost have a negative correlation with overall ranking. These results explain that high ranking cities in the overall ranking have a high density. The people of high ranking cities use more public transportation, bike and walk to their commute way. In addition to, the high ranked cities in the overall ranking have stronger planning and land use than low ranked cities. However, the high ranking cities' congestion cost and mean travel time to work is expensive and longer than low ranking cities.

Table 34 The Result of Correlation between SustainLane Overall Ranking and All indicators

	Overall		
	Pearson Correlation	Sig. (2-tailed)	N
Density	**0.598**	**0.000**	**50**
Walk score	0.660	0.000	50
Drive alone	0.743	0.000	50
Public Transportation	0.724	0.000	50
Walking	0.724	0.000	49
Bicycling	0.521	0.000	49
Carpool	-0.421	0.002	50
Motorcycling	0.196	0.177	50
Total Mode of Commute to Work	**0.712**	**0.000**	**50**
Mean Travel Time to Work	-0.369	0.008	50
Traffic Congestion Cost	-0.341	0.018	48
Arterial speed	-0.343	0.017	48
Freeway speed	-0.385	0.007	48
Total Mean Travel Time to Work & Traffic Congestion Cost	**-0.324**	**0.022**	**50**
Mixed Land Use	0.202	0.177	46
Centeredness	0.227	0.129	46
Street Connectivity	0.373	0.011	46
Total Planning and Land Use	**0.421**	**0.004**	**46**

The relationship among the overall ranking and sub-variables; motorcycling has no correlation with overall ranking in the mode of commute to work indicator and mixed land use and centeredness also has no correlation with overall ranking in planning and land use indicator. These results can support the previous Song's study. That study was that the compact city attempts to deliver sustainability in one package. Only when all these indicators or variables are combined they can create synergy by developing a sustainable urban form (Song, 2005). All of these indicator analyses create a new ranking for the 50 cities. It involves sustainable urban form and includes the above four indicators (see Table 34). Also with the overall ranking and new ranking, there is a statistically significant relationship (see Table 35).

Table 35 New Ranking by Analysis

City	Ranking		City	Ranking		City	Ranking	
	Overall	New		Overall	new		Overall	New
Portland	1	6	Albuquerque	18	8	Charlotte	35	42
San Francisco	2	5	Atlanta	19	45	Houston	36	37
Seattle	3	12	Kansas	20	38	Fresno	37	9
Chicago	4	22	San Jose	21	34	El Paso	38	30
New York	5	11	Tucson	22	10	Fort Worth	39	50
Boston	6	2	Jacksonville	23	44	Nashville	40	41
Minneapolis	7	7	Dallas	24	48	Arlington	41	49
Philadelphia	8	13	Omaha	25	19	Long Beach	42	16
Oakland	9	23	San Diego	26	36	Colorado Springs	43	21
Baltimore	10	14	New Orleans	27	4	Indianapolis	44	47
Denver	11	17	Los Angeles	28	27	Virginia Beach	45	45
Milwaukee	12	3	Louisville	29	43	Memphis	46	32
Austin	13	18	Columbus	30	39	Las Vegas	47	29
Sacramento	14	15	Detroit	31	39	Tulsa	48	27
Washington	15	25	Phoenix	32	26	Oklahoma	49	33
Cleveland	16	19	San Antonio	33	35	Mesa	50	24
Honolulu	17	1	Miami	34	30			

As the result of a new ranking, the top city is Honolulu, 2^{nd} city is Boston, and 3^{rd} city is Milwaukee. However, this city has a special characteristic which is located within island. Therefore, this city is exceptional case. Honolulu was 17^{th} city in the SustainLane overall ranking. Also, that city is 20^{th} city in the density, 2^{nd} city in the mode of commute to work, 17^{th} city in the mean travel time to work & traffic congestion cost, and 12^{th} city in the planning & land use. Especially, Honolulu is the most centeredness city in the US cities. The next city is Boston. Thus, in this thesis, regarding the result that Boston is the top city in this thesis analysis. Boston is the 3^{rd} density city, 1^{st} city in the walk variable, and 3^{rd} city in the mode of commute to work. Also, Boston is 3^{rd} city in the mixed land use variable and 3^{rd} city in the planning & land use ranking.

On the other hands, the last city in the new ranking by this thesis analysis is Fort Worth, 49^{th} city is Arlington and 48^{th} city is Dallas. The bottom three cities are all in the Texas. Fort Worth was 39^{th} city in the SustainLane overall ranking. Forth Worth is 33^{rd} city in the mean travel time to work and traffic congestion cost result. Also, Forth Worth is 39^{th} city in density and 42^{nd} city in the planning and land use result. Moreover, in the mode of commute to work result, Forth Worth is 43^{rd} city.

Atlanta is the most moved down cities. This city was 19^{th} in the SustainLane overall ranking but it is 45^{th} city in the new ranking. Atlanta is 26^{th} ranking fell down. This city is 23^{rd} city in the density, 29^{th} city in the mode of commute to work, 41^{st} city in the mean travel time to work & traffic congestion cost, and 46^{th} city in the planning & land use.

Conversely, the most moved up city is Fresno which city is statistically 28th ranking moved up. Fresno is 19th city in the density and 32nd city in the mode of commute to work. Also, it is 3rd city in the mean travel time to work and 1st city in the traffic congestion cost. Thus, Fresno's mean travel time to work is short and traffic congestion cost is cheapest city. Cause of this reason, Fresno is the 2nd city in the mean travel time to work and traffic congestion cost ranking. Beside, this city has a most mixed land use as the top city and strong street connectivity as the 4th city in the street connectivity ranking. In the new planning & land use ranking, Fresno is the 18th city.

Table 36 Correlation with SustainLane Overall Ranking and New Rankings by This Thesis Analysis

		New Ranking
Overall Ranking	Pearson Correlation	.572
	Sig. (2-tailed)	.000
	N	50

Following the SPSS result, there is a correlation between SustainLane overall ranking and new ranking by this thesis analysis, the p-value is lower than 0.05 and the r-values is 0.572. That result means that there is a strong correlation between SustainLane overall ranking and new ranking. On the other words, high ranking cities in the SustainLane overall ranking also high ranked in the new ranking. According to this result, this thesis finds that sustainable cities have a compact city form. The meaning of the new ranking is that the cities' ranking is going up, those cities have stronger compact city form than low ranking cities. Because, new ranking is based on only four indicators which are most representative compact city form. In this thesis, the basic hypothesis was that high ranked cities in the SustainLane analysis have a sustainable urban form. In other words, sustainable city has a compact city form. Throughout whole analyses and comparisons in this thesis, the conclusion is that high ranked cities have a compact city form. also, the result of this research found that 1) sustainable city and urban form has a correlation, 2) densities, mode of commute to work, and planning and land use have a strong positive correlation with sustainable city, 3) however, mean travel time to work and traffic congestion cost have a negative correlation with sustainable city, 4) when the variables are combined, the sustainable urban form make more synergy effect.

4.6 Research Limitation

Many previous researches and articles suffer from measurement of sustainability and urban form. There are difficulties to figure out the relationship between sustainability and urban form. Cause, the definitions of the terms ‘sustainability’ and ‘urban form’ are too broad and ambiguity. In this thesis’ analysis also is applied same limitation. First, because of the definitions of terms ‘sustainability’ and ‘urban form’ are not clearly defined. Second, between a compact city and a sprawl urban form, despite of the continuous arguments, this research supposed that compact city is the sustainable city form. Third, the boundary of the cities is not clear and same by all indicators. For example, density used the range of the single city boundary but in the mean travel time to work & traffic congestion cost and planning & land use analyses used metropolitan area. Fourth, all cities' data is not sufficient. Some cities' data are lacked and overlapped. Fifth, among many of indicators which are related with sustainable urban form, this research used only four indicators and fifteen variables. Such limitations are important to remember in the interpretation of the results.

5. CONCLUSION

Despite the many research about sustainability, the United States have been continuing a low-density and automobile-dependent growth paradigm that is clearly inconsistent with the economic, environmental and social of the 21th century. The purpose of this research comprehends the relationship between sustainability and urban form based on the analysis and comparison by four indicators. Cause, this method is a simplified and readily understandable way to measure progress towards sustainability.

As a result of research, about density, sustainable city's density is higher than un-sustainable city. Regarding to mode of commute to work, sustainable city's people more use walk, bike and public transportation. However, related with mean travel time to work and traffic congestion cost, the result shows that sustainable city have long mean travel time to work and expensive traffic congestion cost. In addition, on the freeway and Arterial streets, the speed is lower than un-sustainable city. According to mixed land use and centeredness, sustainability and urban form do not have a correlation but street connectivity has a correlation with sustainable city. However, when these three variables are combined, sustainable cities have correlation with planning and land use.

Also, among all indicators and variables' relationship, this research found several results. At first, high density city has a high percentage of using public transportation, walk, and bike. Also, high density city's walk condition is better than low density city's. Related with density, high density city's mode of commute to work is more sustainable than low density city's mode. However, high density city's mean travel time to work and traffic congestion cost are longer and expensive than low density city’s. Because, the speeds on freeway and arterial streets are low (see Appendix A). Moreover, high density city’s mixed land use and street connectivity is stronger than low density city’s. Along with mean travel time to work, short mean travel time to work city have a large percentage of drive alone. It means sprawl city’s mean travel time to work is shorter than compact city. Beside, traffic congestion has a same result. Sprawl city has a cheap traffic congestion cost than compact city. These results are totally opposite result with previous studies and literature review. The reason of this result is that in the previous studies many researchers based on the short VMT theory however short VMT make more trip and large percentage of drive alone. Therefore, this thesis support that VMT cannot reference of the mean travel time to work and traffic congestion cost. The volume of car on the road, speed on the highway and arterial streets and time zone should be added when the mean travel time to work and traffic congestion cost study. Alongside the planning & land use, high walk scored city’ street connectivity is also high. This result shows that street connectivity makes easier to walk and using public transportation than drive car. Beside, strong centeredness can creates short mean travel time to work and cheap traffic congestion cost.

The conclusion of this research is that, throughout these all result, sustainable city have a compact city form and only one variable or indicator cannot make sustainable city and compact city. When all of the compact city’s variables are combined, the city can be truly sustainable.

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APPENDIX A

Density

Ranking		City	Density (pop/sq mi)	Ranking		City	Density (pop/sq mi)
Overall	Density			Overall	Density		
5	1	New York	27,440.0	41	26	Arlington	3,880.0
2	2	San Francisco	17,322.8	36	27	Houston	3,869.9
6	3	Boston	12,575.3	25	28	Omaha	3,791.2
4	4	Chicago	12,557.7	24	29	Dallas	3,737.0
34	5	Miami	11,580.7	30	30	Columbus	3,589.6
8	6	Philadelphia	11,361.0	50	31	Mesa	3,487.2
15	7	Washington	9,639.0	33	32	San Antonio	3,315.3
42	8	Long Beach	9,275.8	32	33	Phoenix	3,032.0
28	9	Los Angeles	8,173.1	13	34	Austin	3,012.7
10	10	Baltimore	7,882.7	18	35	Albuquerque	2,890.4
9	11	Oakland	7,204.2	22	36	Tucson	2,782.8
3	12	Seattle	7,136.5	38	37	El Paso	2,461.8
7	13	Minneapolis	6,969.1	35	38	Charlotte	2,456.1
31	14	Detroit	6,571.1	39	39	Fort Worth	2,403.7
12	15	Milwaukee	6,296.6	46	40	Memphis	2,215.2
16	16	Cleveland	5,589.5	44	41	Indianapolis	2,186.7
21	17	San Jose	5,421.8	48	42	Tulsa	2,110.8
14	18	Sacramento	4,771.5	43	43	Colorado Springs	2,048.0
37	19	Fresno	4,559.9	45	44	Virginia Beach	1,746.9
17	20	Honolulu	4,371.9	27	45	New Orleans	1,726.8
47	21	Las Vegas	4,256.0	29	46	Louisville	1,447.0
1	22	Portland	4,152.7	20	47	Kansas City	1,440.4
19	23	Atlanta	4,081.6	40	48	Nashville	1,187.7
26	24	San Diego	3,944.9	23	49	Jacksonville	1,053.2
11	25	Denver	3,905.5	49	50	Oklahoma City	909.0

The Mode of Commute to Work

City	Overall Ranking	Carpool %	Carpool Ranking	Drive alone %	Drive alone Ranking	Public Transportation%	Public Transportation Ranking	Walk %	Walk Ranking	Bike %	Bike Ranking	Motor Cycle%	Motor Ranking	Walk score	Walk score Ranking	New Mode Ranking
Portland	1	9.8	38	63.6	12	11.2	15	4.4	12	2.2	2	0.2	16	71	11	9
San Francisco	2	7.1	47	38.7	3	33.0	4	8.8	5	1.8	7	1.0	2	88	1	1
Seattle	3	10.1	33	54.6	7	18.6	8	6.3	7	1.2	11	0.1	21	77	6	5
Chicago	4	10.4	29	51.2	5	26.7	5	5.4	9	0.5	20	0.1	33	78	4	8
New York	5	5.5	50	23.2	1	54.6	1	9.4	4	0.4	22	0.0	36	84	2	12
Boston	6	6.8	49	41.2	4	34.0	3	12.6	1	1.7	9	0.1	17	82	3	3
Minneapolis	7	10.0	35	61.1	11	13.4	11	5.0	10	2.7	1	0.2	12	73	9	4
Philadelphia	8	9.9	36	52.1	6	25.3	6	10.7	2	0.6	19	0.0	37	76	7	10
Oakland	9	10.0	34	57.8	8	15.8	9	2.5	25	1.8	8	0.4	6	71	12	7
Baltimore	10	11.3	18	58.8	9	19.4	7	7.2	6	0.3	29	0.0	37	67	16	13
Denver	11	9.6	40	70.1	17	7.7	19	3.2	15	0.6	16	0.1	27	68	15	20
Milwaukee	12	11.0	22	72.0	21	8.5	18	4.0	13	0.3	28	0.3	9	65	17	15
Austin	13	13.2	9	72.0	20	4.9	23	3.0	17	0.4	23	0.1	19	55	33	18
Sacramento	14	15.8	2	71.7	19	2.8	34	2.5	26	2.1	4	0.8	4	58	24	10
Washington	15	6.8	48	38.2	2	36.4	2	10.4	3	1.5	10	0.1	23	74	8	6
Cleveland	16	8.4	44	70.4	18	13.6	10	2.9	20	0.0	42	0.0	37	62	19	31
Honolulu	17	14.8	4	60.2	10	11.1	16	5.6	8	0.6	18	2.2	1	64	18	2
Albuquerque	18	11.2	21	77.9	33	2.2	40	2.6	23	1.2	12	0.4	7	57	27	23
Atlanta	19	7.2	46	69.0	16	11.7	13	2.9	19	0.1	37	0.1	25	56	28	29
Kansas City	20	10.6	27	79.6	37	1.8	41	2.2	33	0.1	40	0.0	37	48	44	47
San Jose	21	10.1	32	78.2	34	3.8	29	1.7	41	0.4	21	0.3	10	60	21	30
Tucson	22	11.2	20	73.8	27	3.2	32	3.1	16	2.2	3	0.4	5	55	29	16
Jacksonville	23	10.7	25	82.2	48	1.4	44	1.6	42	0.4	25	0.1	20	41	50	45
Dallas	24	14.1	7	75.3	29	4.2	26	2.1	36	0.0	41	0.0	37	54	36	33
Omaha	25	10.2	31	80.8	41	1.3	45	2.1	35	0.2	33	0.0	37	58	25	40
San Diego	26	9.8	37	74.6	28	4.5	25	2.4	29	0.3	26	0.2	15	60	20	28

New Orleans	27	14.1	6	65.5	13	6.3	21	3.3	14	1.1	13	0.0	37	60	22	14
Los Angeles	28	10.6	26	67.7	14	11.3	14	2.9	18	0.6	17	0.1	34	69	14	17
Louisville	29	9.7	39	80.8	40	4.0	28	.	.	.	.	.	.	48	42	48
Columbus	30	7.8	45	81.6	47	3.1	33	2.1	34	0.2	30	0.1	30	55	31	41
Detroit	31	12.1	12	72.2	22	8.5	17	2.5	24	0.1	35	0.1	32	54	35	27
Phoenix	32	14.8	3	72.6	25	4.0	27	1.9	38	0.8	14	0.3	8	55	32	19
San Antonio	33	11.4	17	79.0	35	3.3	31	1.6	43	0.1	39	0.1	18	49	40	34
Miami	34	9.5	41	68.6	15	12.7	12	4.7	11	0.0	42	0.0	37	78	5	23
Charlotte	35	11.6	14	77.6	32	3.3	30	0.9	49	0.2	32	0.0	37	44	48	38
Houston	36	14.4	5	73.3	26	4.9	24	2.6	22	0.3	27	0.0	35	55	30	26
Fresno	37	12.6	11	77.3	31	2.4	37	1.3	47	1.9	6	0.0	37	57	26	32
El Paso	38	10.5	28	80.1	39	2.3	39	1.2	48	0.0	42	0.3	11	46	46	44
Fort Worth	39	11.5	16	81.2	44	1.1	46	2.0	37	0.0	42	0.1	24	48	43	43
Nashville	40	8.9	42	81.3	45	2.3	38	2.3	30	0.4	24	0.1	29	44	49	46
Arlington	41	11.3	19	82.5	49	0.2	50	2.2	32	0.1	36	0.0	37	73	10	35
Long Beach	42	10.7	24	72.3	23	6.9	20	1.5	44	0.6	15	0.2	13	70	13	22
Colorado Springs	43	10.9	23	79.2	36	1.5	42	2.2	31	0.0	42	0.1	26	55	34	36
Indianapolis	44	10.2	30	82.7	50	1.5	43	2.4	28	0.2	34	0.0	37	46	47	49
Virginia Beach	45	8.9	43	81.5	46	0.8	48	1.3	46	0.1	38	0.1	22	51	39	50
Memphis	46	11.6	15	81.1	43	2.6	35	2.4	27	0.0	42	0.1	31	49	41	36
Las Vegas	47	11.7	13	76.5	30	5.0	22	2.8	21	0.0	42	0.2	14	59	23	25
Tulsa	48	12.9	10	79.6	38	0.8	47	1.9	39	0.0	42	0.0	37	53	38	42
Oklahoma City	49	13.2	8	80.9	42	0.7	49	1.7	40	0.2	31	0.1	28	47	45	39
Mesa	50	17.0	1	72.4	24	2.5	36	1.4	45	1.9	5	0.8	3	53	37	21

The Mean Travel Time to Work and Traffic Congestion Cost

City	Overall Ranking	Mean Travel Time to Work	Mean Travel Time to Work Ranking	Traffic Congestion Cost	Traffic Congestion Cost Ranking	Arterial Street Speed	Arterial Street Speed Ranking	Freeway Speed	Freeway Speed Ranking	New Mean Travel Time to Work & Traffic Congestion Cot
Portland	1	24.3	26	625	25	27.9	22	44.1	30	25
San Francisco	2	29.3	44	2,414	39	25.5	44	39.4	45	47
Seattle	3	24.8	29	1,413	31	27.8	25	43.2	34	28
Chicago	4	34.4	49	3,968	44	24.3	48	39.1	47	50
New York	5	39.8	50	7,383	45	26.1	40	40.5	40	48
Boston	6	29.3	45	1,820	34	28.3	17	45.6	24	29
Minneapolis	7	21.9	12	1,099	28	28.9	13	44.7	27	18
Philadelphia	8	31.1	48	2,076	35	27.5	28	45.6	25	37
Oakland	9	27.9	41	2,414	39	25.5	45	39.4	46	46
Baltimore	10	28.8	43	1,126	29	27.6	27	44.6	28	31
Denver	11	24.1	24	1,176	30	26.4	36	44.1	31	30
Milwaukee	12	21.7	11	282	12	32.1	1	49.4	20	9
Austin	13	23.1	16	422	20	26.6	35	45.1	26	24
Sacramento	14	23.3	17	729	26	26.2	39	43.9	32	26
Washington	15	30.1	47	2,331	38	25.0	46	43.1	35	44
Cleveland	16	24.6	28	236	10	31.6	3	55.5	5	12
Honolulu	17	23.6	19	166	6	27.5	29	50.3	15	17
Albuquerque	18	21.2	8	200	8	30.0	10	49.9	17	8
Atlanta	19	25.7	34	2,581	41	26.8	34	42.5	36	41
Kansas City	20	21.3	9	256	11	32.1	2	55.8	3	5
San Jose	21	26.1	37	899	27	25.7	42	43.5	33	40
Tucson	22	21.4	10	338	14	27.9	23	50.5	14	14
Jacksonville	23	23.9	23	376	15	26.3	38	53.1	7	20
Dallas	24	25.9	36	2,747	43	28.3	18	40.5	41	38
Omaha	25	17.3	1	154	4	29.4	12	53	8	5
San Diego	26	23.8	21	1,708	33	25.8	41	40.8	39	35
New Orleans	27	23.3	18	207	9	29.5	11	53.3	6	9

Los Angeles	28	29.5	46	9,325	46	25.6	43	34.7	48	49
Louisville	29	24.9	30	395	16	28.1	21	48.6	22	21
Columbus	30	20.9	6	409	18	28.8	15	50.2	16	13
Detroit	31	26.8	39	2,174	36	26.4	37	47.6	23	36
Phoenix	32	25.7	35	1,687	32	27.9	24	42	38	32
San Antonio	33	23.8	22	530	23	27.7	26	48.8	21	22
Miami	34	27.9	42	2,730	42	24.9	47	42.1	37	45
Charlotte	35	24.2	25	409	19	27.4	30	49.7	18	22
Houston	36	26.2	38	2,225	37	27.4	31	40.3	44	42
Fresno	37	20.2	3	127	1	30.1	9	55.7	4	2
El Paso	38	21.9	13	159	5	30.3	8	49.5	19	11
Fort Worth	39	24.3	27	2,747	43	28.3	19	40.5	42	33
Nashville	40	23.7	20	404	17	28.8	16	52.6	9	15
Arlington	41	25.6	32	2,747	43	28.3	20	40.5	43	38
Long Beach	42	27.6	40	.	.	.		.	.	43
Colorado Springs	43	20.5	4	131	2	30.6	7	52.3	10	4
Indianapolis	44	22.1	14	478	22	27.3	32	51.9	12	18
Virginia Beach	45	23.0	15	467	21	28.9	14	50.8	13	16
Memphis	46	20.9	7	317	13	31.2	5	52.2	11	7
Las Vegas	47	25.1	31	543	24	27.3	33	44.2	29	27
Tulsa	48	17.7	2	149	3	31.1	6	58.2	1	1
Oklahoma City	49	20.6	5	171	7	31.5	4	56.2	2	3
Mesa	50	25.6	33	.	.	.		.	.	34

Planning and Land Use

City	Overall Ranking	Mixed Land Use	Mixed Land Use Ranking	Centeredness	Centeredness Ranking	Street Connectivity	Street Connectivity Ranking	New Planning Ranking
Portland	1	59.2	26	72.8	8	76.7	7	6
San Francisco	2	62.1	17	76.9	5	83.8	2	2
Seattle	3	45.9	42	58.6	26	70.2	14	29
Chicago	4	66.6	13	51.3	36	80.9	5	12
New York	5	75.1	2	86.4	2	92.9	1	1
Boston	6	71.9	3	65.4	15	71.4	12	3
Minneapolis	7	54.8	33	64.4	18	52.6	40	34
Philadelphia	8	69.1	7	57.3	28	67.7	17	10
Oakland	9	61.5	20	34.4	46	80.0	6	25
Baltimore	10	61.8	19	69.1	12	63.1	21	10
Denver	11	66.9	12	65.1	16	75.4	8	5
Milwaukee	12	68.2	10	70.4	10	56.3	35	14
Austin	13	64.7	14	69.2	11	56.6	34	20
Sacramento	14	64.1	15	52.2	34	59.0	26	26
Washington	15	45.5	43	58.5	27	58.8	27	38
Cleveland	16	62.1	17	60.3	24	40.0	45	32
Honolulu	17	48.8	38	100.0	1	68.5	15	12
Albuquerque	18	60.0	23	74.1	6	70.6	13	7
Atlanta	19	42.6	45	49.2	37	34.2	46	46
Kansas	20	57.8	29	53.2	33	53.2	38	40
San Jose	21	55.9	31	56.1	30	75.1	9	24
Tucson	22	70.4	6	63.6	19	52.8	39	22
Jacksonville	23	42.2	46	61.0	22	62.7	22	33
Dallas	24	47.8	39	48.5	39	54.1	37	45
Omaha	25	69.0	8	79.1	4	62.7	23	4
San Diego	26	61.0	21	44.5	40	63.5	20	27

New Orleans	27	46.5	40	73.9	7	83.1	3	9
Los Angeles	28	71.2	4	43.3	43	73.9	10	15
Louisville	29							
Columbus	30	44.2	44	60.7	23	58.3	30	38
Detroit	31	59.3	25	37.7	45	55.8	36	44
Phoenix	32	67.1	11	55.3	32	64.3	19	21
San Antonio	33	58.2	28	64.8	17	61.8	24	23
Miami	34	60.6	22	55.4	31	81.8	4	15
Charlotte	35							
Houston	36	63.7	16	52.0	35	57.3	33	30
Fresno	37	75.2	1	67.3	14	43.8	43	18
El Paso	38	59.8	24	71.4	9	61.3	25	18
Fort Worth	39	51.5	34	44.2	41	58.5	28	42
Nashville	40							
Arlington	41	51.5	34	44.2	41	58.5	28	42
Long Beach	42	71.2	4	43.3	43	73.9	10	15
Colorado Springs	43	68.8	9	80.8	3	58.0	31	8
Indianapolis	44	55.6	32	61.2	21	50.7	41	37
Virginia Beach	45	50.4	37	49.0	38	67.8	16	34
Memphis	46	56.1	30	62.3	20	45.9	42	36
Las Vegas	47	46.3	41	59.7	25	65.2	18	30
Tulsa	48	50.9	36	68.7	13	57.7	32	27
Oklahoma City	49	58.6	27	57.1	29	41.4	44	40
Mesa	50							

All Indicators Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1												
2	.60(**)	1											
3	-.421(**)	-.347(*)	1										
4	.743(**)	.798(**)	-0.228	1									
5	.724(**)	.826(**)	-.400(**)	.923(**)	1								
6	.724(**)	.627(**)	-.379(**)	.786(**)	.791(**)	1							
7	.521(**)	.383(**)	-0.055	.553(**)	.395(**)	.363(*)	1						
8	0.196	0.108	0.077	0.177	0.081	0.019	.505(**)	1					
9	.660(**)	.883(**)	-.400(**)	.802(**)	.770(**)	.743(**)	.486(**)	0.115	1				
10	.712(**)	.756(**)	-0.066	.915(**)	.801(**)	.774(**)	.718(**)	.406(**)	.819(**)	1			
11	-.369(**)	-.680(**)	0.272	-.618(**)	-.710(**)	-.441(**)	-0.194	0.025	-.551(**)	-.488(**)	1		
12	-.341(*)	-.600(**)	0.277	-.459(**)	-.540(**)	-.401(**)	-0.132	0.059	-.501(**)	-.397(**)	.840(**)	1	
13	-.343(*)	-.527(**)	0.195	-.455(**)	-.500(**)	-.337(*)	-0.284	-0.159	-.402(**)	-.417(**)	.700(**)	.698(**)	1
14	-.385(**)	-.613(**)	0.156	-.484(**)	-.523(**)	-.368(*)	-0.229	-0.185	-.552(**)	-.491(**)	.753(**)	.899(**)	.696(**)
15	-.324(*)	-.664(**)	0.237	-.536(**)	-.604(**)	-.346(*)	-0.217	-0.073	-.540(**)	-.464(**)	.914(**)	.943(**)	.840(**)
16	0.202	.380(**)	-0.033	.307(*)	0.222	0.156	.310(*)	0.017	.332(*)	.292(*)	-0.152	-0.025	-0.037
17	0.227	-0.097	-0.039	0.111	0.025	0.256	0.149	0.123	0.06	0.166	.391(**)	.582(**)	.332(*)
18	.373(*)	.437(**)	-0.29	.464(**)	.417(**)	.322(*)	.372(*)	0.229	.586(**)	.477(**)	-.517(**)	-.358(*)	-.508(**)
19	.421(**)	.368(*)	-0.168	.476(**)	.358(*)	.396(**)	.425(**)	0.185	.516(**)	.499(**)	-0.139	0.117	-0.102
20	.572(**)	.489(**)	-0.027	.678(**)	.509(**)	.582(**)	.655(**)	.363(*)	.629(**)	.770(**)	-0.007	0.193	0.067

14	15	16	17	18	19	20
1						
.914(**)	1					
-0.109	-0.114	1				
.452(**)	.508(**)	0.143	1			
-.447(**)	-.496(**)	0.174	0.097	1		
-0.045	-0.043	.638(**)	.622(**)	.659(**)	1	
0.049	0.094	.484(**)	.622(**)	.355(*)	.765(**)	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

1. SustainLane Overall Ranking, 2. Density, 3. Carpool, 4. Drive alone, 5. Public Transportation, 6. Walk, 7. Bike, 8. Motorcycle, 9. Walk score, 10. Mode New Ranking, 11.Mean Travel Time to Work, 12. Traffic Congestion Cost, 13. Arterial Streets Speed, 14. Freeway Speed, 15. Mean Time & Cost New Ranking, 16. Mixed Land Use, 17. Centeredness, 18. Street Connectivity, 19. Planning & Land Use New Ranking, 20. New Ranking

VITA

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